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FINAL REPORT FOR RESEARCH AGREEMENT
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"Ecological Characterization and Restoration Alternative
for Sawmill Creek Research Natural Area, Bitterroot ... "
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Ecological Characterization and Restoration Alternatives for Sawmill Creek Research Natural Area, Bitterroot National Forest, Montana

by

Pamela G. Sikkink

Final Report to U. S. Forest Service

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Ecological Characterization and Restoration Alternatives for Sawmill Creek Research Natural Area, Bitterroot National Forest, Montana

by
Pamela G. Sikkink

Abstract

Sawmill Creek Research Natural Area is a diverse ecosystem consisting of five distinct communities. These communities contain over 240 species in 48 families. Historically, the floral composition and structure of these communities were controlled by frequent, low-intensity ground fires. Detrended correspondence analysis (DCA) shows that the vegetation in these communities today is controlled mainly by physical and physiologic factors, including evapotranspiration, aspect and the amount of overstory cover sheltering understory plants.

Like composition, structure in these communities were historically controlled by fire. Today, structure is controlled mainly by invasion. Douglas-fir invasion of the grassland and forests is documented in this study using basal area and percent cover data. Douglas-fir (*Pseudotsuga menziesii*) comprised 57% of a typical forest plot (BA=15.1 m2/hectare). It also dominated the lower-size classes (dbh=5-29 cm) in the canyon forest, mixed-tree savannah, and riparian communities. Similarly, grasslands are invaded by weeds, shrubs and trees. Weed species comprised up to 14% of the total flora in grassland plots.

Landscape analysis using 1937 and 1993 aerial photos revealed that similar structural changes occurred within the landscape and the RNA. In 60 years, both RNA and the surrounding landscape (non-RNA) lost grassland acreage due to tree and shrub invasion. Grassland acreage decreased almost 10% in the RNA and almost 9% on non-RNA land. Grassland-tree and grassland-shrub covers increased 11% and 3%, respectively, in the RNA. Changes were much less significant on non-RNA land. The RNA's closed forest reduced acreage from 1937 to 1993. On non-RNA land, the percentage of closed forest actually increased by 8% of the total area. Paired t-tests showed the differences between cover types acreage on RNA and non-RNA land were significant at $p<.05$.

Recommendations for restoration in the RNA are proposed based on short- and long-term objectives for the RNA. The single-most important recommendation for long-term management is to restore the natural process of fire. Fire created and maintained the vegetation targeted for preservation in the RNA in the past. Fire needs to be restored to ensure that these communities persist into the future.

Introduction

Sawmill Creek Research Natural Area (RNA) contains some of the best examples of low-elevation, mixed-conifer and bunchgrass ecosystems remaining in western Montana. The RNA was established in 1992 to protect these ecosystems into perpetuity under the most natural conditions possible. In 1992, the RNA admittedly was not in pristine condition (Habeck and others, 1992). The purpose of this study is to characterize the ecosystems of Sawmill Creek RNA and determine to what extent the ecosystems are degraded. What processes acted, or are acting, to degrade them? What alternatives exist to reverse the degradation process?

Historically, low-elevation conifer/bunchgrass and shrubfield/conifer ecosystems like those of Sawmill Creek had distinct characteristics. Compositionally, ponderosa pine (*Pinus ponderosa*) dominated basal area (72%) with some Douglas-fir (*Pseudotsuga menziesii*) (9%) and western larch (*Larix occidentales)* (19%) (Habeck, 1994). South-slope shrubs and grasses included bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Fescue idahoensis*), and rough fescue (*Fescue scabrella*) and snowberry (*Symphoricarpos albus*) (Habeck, 1994). North slope vegetation included ponderosa pine, Douglas-fir, ninebark (*Pysocarpus malvaceus*) and sometimes larch (Habeck, 1994) depending on overall moisture available at the site. Structurally, these systems were open and park-like (Brown and others, 1995; Arno, 1976; Arno, 1980). Ponderosa pines had clear trunks with the lowest branches high above the ground. Douglas-fir was a minor component of the forest because frequent fires killed seedlings. Debris from broken trees or windfall was sparse because surface fires kept it from accumulating on the ground. Fires returned at five to 30 year intervals to maintained the open structure (Arno, 1996), usually burning several thousand acres each year on the landscape (Brown and others, 1995). In Sawmill Creek, however, the natural process of fire has not been allowed to operate for over 60 years. It is assumed that

so many years of fire suppression resulted in degraded conditions in these forest ecosystems, which rely on ground fire for controlling regeneration, disease, understory vegetation, and fuel buildup.

Like the forest ecosystems, the grasslands of western Montana and the central Columbia Plateau had distinct characteristics before European settlement. The grasslands were comprised mainly of bluebunch wheatgrass (*Agropyron spicatum)* (Harris 1967). These grasslands were "dominated by perennials in a variety of life forms and with wide floristic diversity" (Bedunah, 1992, p.8). Grazing and fire were the key processes to maintain primary production and forage quality (Knapp and Seastedt, 1986; McNaughton and others, 1988; Dudley and Lajtha, 1993). Although we cannot know the exact frequency and intensity of these disturbance events in historic grasslands because there are no trees with fire scars recording disturbance events, fire frequency can be roughly extrapolated from fire scars in the ponderosa pine forests of western Montana. According to Wright and Bailey (1980), frequencies of 2 to 25-years are very reasonable for the historic grasslands of the Rocky Mountain west.

Grazing and fire were both beneficial and detrimental processes in historic grasslands. The benefits of these processes to grasslands are summarized in many studies (Wright and Bailey, 1980, Daubenmire, 1928, Collins and Wallace, 1990). Grazing increases the availability of nitrogen to grasses and herbs in these ecosystems, which are normally nitrogen-limited. When grasses are removed, both inter- and intra- specific competition for nitrogen is affected (Steele, 1987). Fire affects the mobility of nitrogen, the quantity of inorganic nitrogen, the surface porosity for water infiltration and leaching of nitrogen, the soil water potential, the soil temperature, the primary productivity and the plant composition of the grasslands (Dudley and Lajtha, 1993; Wright and Bailey, 1982; Redman and others, 1993). Changes in the nitrogen budget and water availability affect biomass production. Some studies show plants with greater vigor and biomass after disturbance (Dudley and Lajtha, 1993; Knapp and Seastedt, 1986). Others show evidence to the contrary (Whisenant and Uresk, 1989; Redmann, R.E., 1978). The ultimate effect depends on the timing, intensity and interaction of the disturbance event(s) (Wright and Bailey, 1980; Redman and others, 1993). Overgrazing, caused by economic pressures to raise more cattle on limited acreage, gradually destroyed the historic bluebunch wheatgrass communities of western Montana and the Colorado Plateau (Harris, 1987). Overgrazing caused conversion of many acres of

grassland to sagebrush (Hull and Hull, 1974). Overgrazing was also one of the main causes of infestation of western grasslands by annual weed species (Harris, 1987). Like the conifer/bunchgrass forest ecosystems, it is assumed that the grasslands of Sawmill Creek will exhibit signs of degradation because the process of fire has not been allowed to operate for over 60 years.

Sawmill Creek RNA is a very "permeable landscape." It is a very small area within a region that has experienced many changes in both time and space. The RNA's abundant, permeable edge creates an environment easily influenced by any changes that occur on the surrounding landscape and increases susceptibility of the RNA to the same degrading forces. Changes in vegetation and land-use in the landscape surrounding Sawmill Creek affect nutrient pools, plant composition and structure, wildlife movements and food, wildlife cover, soil texture, water movement and many other characteristics within the RNA itself. Wildlife increasingly concentrate forage activities in the RNA as the surrounding natural grasslands are converted to agricultural land. Natural succession, invasion, and anthropogenic activities result in acreage loss for some communities and acreage gain for others. Changes in patch size and shape affect where nutrients are located and how wildlife use them both on the surrounding landscape and within the RNA. Patch changes affect the continuity and characteristics of wildlife cover and habitats. They also affect the conditions available to grow the target vegetation in the RNA. Forests that experience canopy closure through natural succession and invasion from areas outside the RNA are unlikely to perpetuate the target vegetation in this RNA because the vegetation requires grassland to open-canopy conditions to thrive. This study assumes that many changes have occurred on the landscape in the past 60 years that directly affect vegetation and wildlife use in the RNA. Because the RNA is so small, these changes need to be viewed in the landscape context to determine which processes appear to be natural and operating over the whole area and what external factors influence vegetation growth in the RNA. This study examines if any or all of these factors act to degrade Sawmill Creek RNA and recommends restoration alternatives, if necessary, to ensure long-term survival of the vegetation targeted for protection.

To characterize the plant communities on the RNA, I made percent cover estimates for each species found in established study plots, as well as collected plant specimens from the entire RNA. I visually classified structure, measured all tree diameters, measured all coarse woody debris > 5cm in

diameter, and collected core bores from selected trees in each study plot. To determine how the landscape surrounding Sawmill Creek changed over the past 60 years, I mapped vegetation cover from 1937 and 1993 aerial photography, divided the two maps into 2.5 acre grid cells, and classified each grid cell according to cover type.

This paper is divided into four parts. Chapter 1 covers the characterization of the RNA and factors degrading the RNA from inside its boundaries (i.e. site analysis) that can be controlled by RNA management policy. Chapter 2 analyzes landscape changes around the RNA during the past 55 years and factors affecting the RNA from outside its boundaries that must be controlled by management policies of other entities but directly affect RNA ecology. Chapter 3 covers alternatives for restoration and specific recommendations for Sawmill Creek RNA. Chapter 4 proposes an action plan for implementing restoration recommendations

Chapter 1: Site Analysis

Introduction

The objectives of site analysis are to determine the composition and structure of the plant communities currently present in the RNA. Site analysis serves three purposes. First, it provides data on current conditions in the RNA to determine how the composition and structure differ from the characteristics typical of these communities in the past. Second, site analysis can be used to identify critical species and interactions that must be maintained in the RNA to protect diversity and function. Third, it provides a data base upon which to measure future change in the RNA and assess whether management techniques are successful.

Methods

Site description

Sawmill Creek Research Natural Area (RNA) is located on the lower slopes of the Sapphire Range in the Bitterroot National Forest near Stevensville, Montana (Figure 1). The RNA consists of 270 acres (109 hectares) that support a variety of communities, ranging from riparian forests near Sawmill Creek to dry, exposed mountain grasslands. In 1987, the site was mapped by Losensky for conifer and bunchgrass habitat types (Pfister et al, 1977). At that time, the RNA consisted of 14% "forested scree habitat type", 37% savannah or open to closed forest dominated by Douglas-fir (*Pseudotsuga menziesii)* and ponderosa pine (*Pinus ponderosa),* and 40% grassland with minor, widely scattered conifers. In 1992, the area was established as a RNA to protect the best remnants of specific conifer/bunchgrass habitat types in the west. These habitat types include:

1) Ponderosa pine/ Idaho fescue (*Pinus ponderosa/Festuca idahoensis*);

2) Douglas-fir/ Idaho fescue (*Pseudotsuga menziesii/Festuca idahoensis*);

3) Douglas-fir/ bluebunch wheatgrass (P*seudotsuga menziesii/Agropyron spicatum*);

4) Idaho fescue/ bluebunch wheatgrass (*Festuca idahoensis/Agropyron spicatum*); and

5) Rough fescue/ Idaho fescue (*Festuca scabrella/Festuca. idahoensis*) (Habeck et al, 1992).

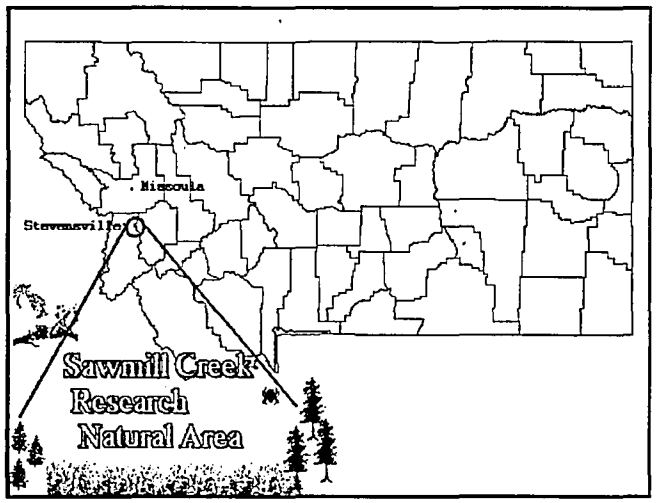


Figure 1: Location of study area

Elevation within the RNA ranges from 1413 m (4635 ft) at the southwest corner of the RNA to 1658 m (5440 ft) at the northern boundary (Habeck et al, 1992). Soils are variable in type and thickness. Riparian soils are thick, organic rich mollisols or alluvial gravels (Habeck et al, 1992). Talus slopes are steep and have little soil development. Grasslands have dominantly dark, organic-rich horizons up to 25 cm (10 in) thick (Habeck et al, 1992). Parent material for the soils is mostly quartzites and argillites of the Precambrian Belt Series, which comprises this area of Montana (Alt and Hyndman, 1986). Between Sawmill Creek and Stevensville, the foothill benches consist of sediments deposited during the last glacial age (Habeck et al, 1992).

The flora of the grasslands and forests in Sawmill Creek is controlled, in general, by climate. Edaphic control of vegetation is restricted to the canyons where physical topographic characteristics create cooler, moister microclimates. Climatic conditions at Sawmill Creek are unique to the Bitterroot Valley. Although much of the valley is influenced by Pacific air masses from the west, Sawmill Creek RNA lies in a "rain shadow" and does not receive much moisture from these air masses (Habeck et al, 1992). Mean annual temperature is 6.8°C (44° F). Mean annual precipitation is approximately 333.3 mm (13 in) per year. Winters are long and cold. Mean January temperature and precipitation values are -5°C (22.8°F) and 1.32 inches, respectively (Habeck et al, 1992). Summers are short, hot and dry. July temperatures average 65.5°F and precipitation averages .76 inches (Habeck et al, 1992).

Vegetation sampling

I collected voucher specimens of both understory and overstory species thoughout the study area from July-October, 1995, and from May-June, 1996 to create a species list for the RNA (Appendix A). The species collection resides at the USFS Intermountain Research Station herbarium in Missoula, MT. Nomenclature follows Hitchcock and Cronquist (1973) and Lackschewitz (1991).

In August, 1995, I established 33 permanent study plots in the RNA that were arranged on a systematic grid at 1000 ft. (333 m) spacing east-west, 500 ft (151 m) north-south (Figure 2). Initial plot spacing was geometrically predetermined to get uniform coverage of the RNA. The starting point for the first plot, however, was randomly assigned. I established two extra plots in the forests because I lacked data for this important community when the original grid sampling was complete.

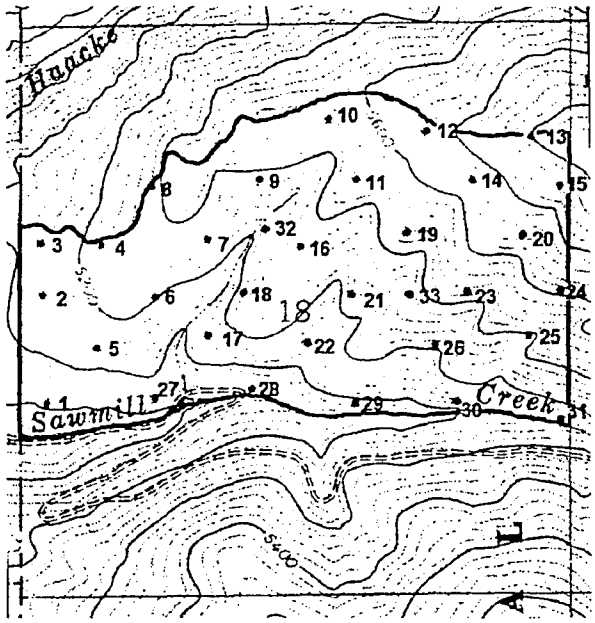


Figure 2: Permanent plot locations, Sawmill Creek RNA

Field procedures

Each study plot was circular, .10 hectare (35.6 m in diameter), and marked at the center with rebar and a permanent metal tag. I estimated relative abundance for each overstory and understory plant species in the entire .1 hectare using five cover classes established by Braun-Blanquet (Mueller-Dombois

and Ellenburg, 1974). I assigned a field structural classification to each plot using a preliminary classification developed by Pfister (1994) for the Bitterroot Mountains. I measured the diameter at breast height (dbh) for all trees greater than 5 cm dbh in each plot and recorded condition (live/dead), dominance, number of cohorts and disturbance evidence. Keen's (1943) classification was used to assign a vigor class to all ponderosa pines in the plot to determine their overall condition and whether they still contained straight clear boles. Height and canopy depth were calculated trigonometrically using horizontal distances and vertical angles. I used a tape measure to measure horizontal distances to each tree and a clinometer to measure vertical angles to base of tree, base of crown, and top of tree. Horizontal distances were adjusted, when necessary, to keep vertical angles less than 60° for minimal error. At least one tree from each species was randomly selected in each plot for the tree-height measurements. Crown ratio was calculated as crown height/total height. I cored selected trees at dbh from each species to determine age and estimate growth rates. I measured all coarse woody debris (CWD) in each plot recording a small end diameter, large end diameter, and length to calculate volume using Smalian's formula (i.e. vol=Pi*(((dia 1 +dia 2)/4)^2)*length)). Decay class was assigned to the coarse woody debris using Thomas and others (1979). Coarse woody debris less than 5 cm in diameter on the large end was ignored. In some plots, this ignored a significant volume of debris that would be important for flammability.

Data analysis

Cluster analysis was done on two data sets to determine overall community structure. The first data set included all species that occurred in the study plots (184 species; Appendix B). The second data set consisted of only those species that met high constancy criteria (77 species; Appendix C). Constancy criteria included species that were found in more than 20% but less than 80% of the plots (Barber, 19**). I ran cluster analysis first on all species in each data set and, second on a data set that contained all species plus slope, aspect and elevation. Analysis was performed using SYSTAT on a PC DOS platform (Wilkinson, 1988). This study used Euclidean criteria and tested both Ward's and largest distance techniques. The results presented in this paper summarize only the analysis using vegetation data because

adding elevation resulted in clusters based only on elevation. No major grouping differences were found using Ward's or largest distance, so Ward's technique is used for the community groupings in this paper.

To determine relationships between clusters and environmental factors, I used detrended correspondence analysis (DCA) within PCOrd (Hill, 1980) on a PC DOS platform. There was no downweighting of species. PCOrd was also used to calculate **richness** (S= number of non-zero species in plot), **Shannon-Weaver diversity index** (**H'** = - sum (Pi*ln(Pi)) after Peet, 1974) and **evenness** (**E** = H/ln (richness)) for each plot. I used standard statistical procedures to calculate mean, standard deviation and variance of community and structural characteristics.

I used frequency tables within SYSTAT to calculate number of species by family, number of weedy and natural species, and number of annual and perennial species. I classified annual/perennial and natural/weedy species based on plant origins and descriptions by Lackschewitz (1991).

Basal area for structural analysis was calculated using $\sum i$ (10*(3.14159*(DBH/2)^2))/10000, I=1 to n. Basal area data from this study was compared to a similar western Montana conifer/bunchgrass community from Pattee Canyon near Missoula, Montana. Habeck (1994) investigated the changes in basal area that occurred in Pattee Canyon forests between 1901 and 1992 on both a north and south slope. Habeck's north aspect consisted of a Douglas-fir/ninebark (*Pseudotsuga menziesii/Physocarpus malvaceous*) habitat type (*Physocarpus malvaceous* phase). He lumped north aspect and moist ravines together in his analysis.

Results

Results of site analysis support the hypotheses that the plant communities of Sawmill Creek RNA are biologically diverse in composition with structural characteristics atypical of the open-canopy, ponderosa pine forests and open grasslands that were historically present in western Montana. Five distinct communities comprise the RNA. Detrended correspondence analysis (DCA) indicates that the main process controlling the composition of these communities today is not fire, but moisture availability.

I found that all of the communities had changed structurally from historical conditions. The grasslands exhibit several signs of structural change and degradation, including high proportions of weeds, potentially threatening proportions of shrubs and junipers, and poor production of seed-bearing

stems. The basal area and percent cover analyses indicate that most of the forests are now dominated by Douglas-fir, not ponderosa pine. Vigor class analysis indicates ponderosa pine is in poor health in some communities of the RNA with deformed crowns and abundant dead branches. Several species of trees exhibit signs of insect and disease and have poor regeneration. Coarse woody debris has accumulated on the forest floor from past logging, windthrow and other processes. Accumulated debris puts the targeted communities at risk of catastrophic fire in the RNA.

Community Composition

Study plots within the RNA group into five distinct physiognomic types according to my cluster analysis. These communities include grassland, shrub savannah, mixed tree and shrub savannah, canyon forest and riparian forest (Figure 3). Voucher specimens represent 240 species in 48 families (excluding mosses and lichens) and attest to the diversity found within these five communities (Appendix A).

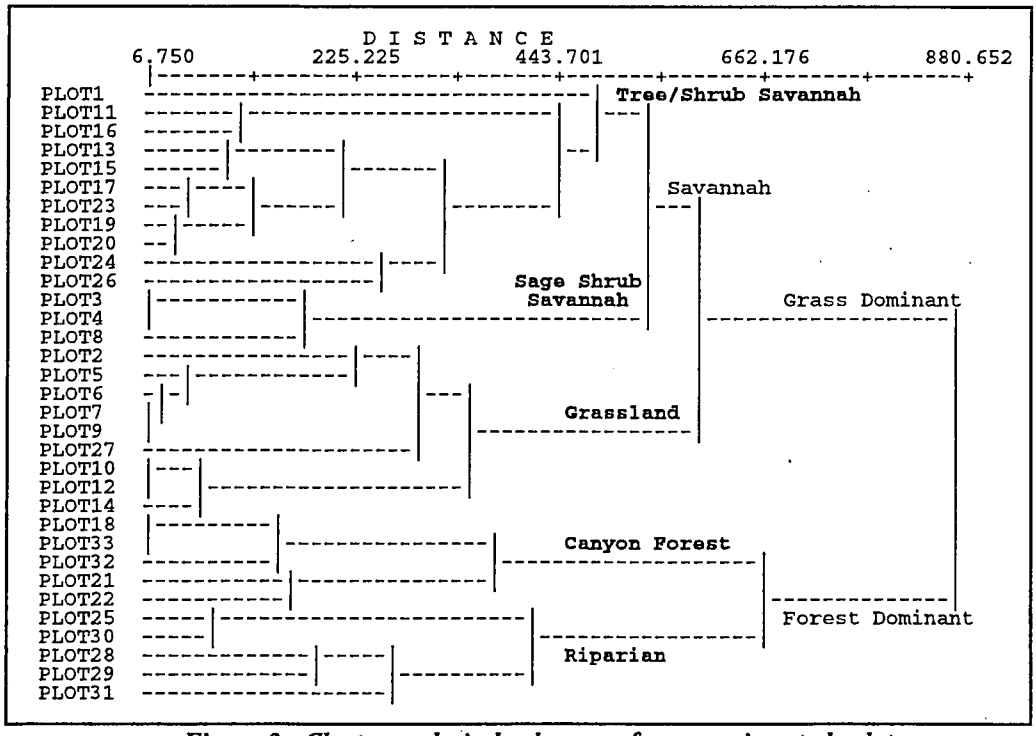


Figure 3: Cluster analysis dendrogram for grouping study plots

The grassland is an environment dominated by drought-tolerant plants. Rich yellow, red and blue species of arrowleaf balsamroot (*Balsamorhiza sagittala*), lupine (*Lupinus sp.*), paintbrush

(*Castilleja sp.*), yellow salsify (*Tragopogon dubius*), hairy golden aster (*Chrysopsis villosa*) and pale alyssum (*Alyssum alyssoides*) dominate this community from spring to late summer. It also contains a wide variety of species from the composite, cruciferae, borage, scrophulariaceae, and umbelliferae families throughout the growing season (Table 1; Appendix B). Bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*) and rough fescue (*Festuca scabrella*) are the dominant grasses. Cheat grass (*Bromus tecturm*), spotted knapweed (*Centaurea maculosa*) and St. John's wort or goatweed (*Hypericum perforatum*) are the most common weedy species invading areas of the grassland.

***Table 1*: Mean number of species in most common families in RNA by community**

	Total Family	*Boraginaceae*	*Caryophyllaceae*	*Compositae*	*Cruciferae*	*Gramineae*
		Borage	*Pink*	*Aster*	*Mustard*	*Grass*
Grassland	17.0	0.4	0.3	6.2	2.1	6.3
Sav Shrub	19.7	0.0	0.0	13.0	0.0	6.0
Mix Sav	19.3	0.0	0.3	7.6	0.6	5.6
Forest	18.0	0.0	0.0	5.0	0.6	4.6
Riparian	21.4	0.0	0.0	5.8	1.4	5.4

	Leguminosae	*Lilaceae*	*Ranunculaceae*	*Rosaceae*	*Scrophulariaceae*	*Umbelliferae*
	Pea	*Lily*	*Buttercup*	*Rose*	*Figwort*	*Parsley*
Grassland	0.7	1.0	0.0	0.0	2.3	0.3
Sav Shrub	0.0	3.0	0.0	1.3	2.7	0.0
Mix Sav	0.3	2.6	0.0	1.6	3.9	0.4
Forest	0.0	2.0	0.0	2.8	0.6	0.0
Riparian	0.0	0.6	0.6	3.8	1.2	0.6

Big sagebrush (*Artemisia tridentata*) characterizes the shrub-dominated savannah. This colorful community consists of silvery-green sagebrush (*Artemisia tridentata*) , yellow-green rabbitbrush (*Chrysothamnus viscidiflorus*), yellow and purple owl clover (*Orthocarpus tenuifolius*), Deptford pink (*Dianthus armeria*), white rosy pussytoes (*Antennaria microphylla*) and yellow sulphur buckwheat (*Eriogonum umbellatum*). It also contains scattered ponderosa pine or Rocky mountain juniper trees. Rough fescue equals bluebunch wheatgrass abundance in this community. With the exception of pale alyssum (*Alyssum alyssoides*), members of the crucifer (mustard) family are conspicuously absent (Table 1). Spotted knapweed and cheatgrass are the pervasive weedy species.

The mixed-tree and shrub savannah consists of scattered ponderosa pine and Douglas-fir on open slopes dominated by drought-tolerant plants, such as arrowleaf balsamroot, lupine and paintbrush. Most sample plots in this classification also contain Rocky Mountain juniper (*Juniperus scopulorum*). The understory is dominated by bluebunch wheatgrass, interrupted bentgrass and a greater diversity and abundance of herbs than the grasslands. Common snowberry (*Symphoricarpos albus*) is characteristic to most of the plots along with one or more other shrubs, such as sagebrush, wax current (*Ribes cereum*), serviceberry (*Amelanchier alnifolia*) or chokecherry (*Prunus virginiana*). Weedy invaders include spotted knapweed, tall annual willow herb (*Epilobium paniculatum*), pale alyssum, mountain tansy mustard (*Descurainia richardsonii*) and Jim Hill mustard (*Sisymbrium altissimum*), prickly lettuce (*Lactuca serriola*) and sulphur cinquefoil (*Potentilla recta*).

Rocky mountain juniper, ponderosa pine, and Douglas-fir characterize the overstory in the canyon forest. Understory shrub species vary with location in the RNA (Appendix B). The herbaceous vegetation is much more depauperate than in the previous communities. The richness of these plots varies from 22 to 42 species (mean=33). The main grasses are pine grass (*Calamagrostis rubescens*) and Idaho fescue. With the exception of minor cheatgrass and pale alyssum, the canyon forest lacks weedy species.

The riparian forest exists at an ecotone between a very steep, rocky environment and a flat, water-soaked environment. Large expanses of talus exist near stream's edge along much of the eastern half of the RNA. Therefore, several plots contain one-half dry, hot, soil-deficient talus and one-half very wet, cool, aquatic or hydric soils to the stream's edge. The talus areas are dominated by mockorange (*Philadelphus lewisii*), serviceberry (*Amelanchier alnifolia*), chokecherry (*Prunus virginiana*), and ninebark (*Pysocarpus malvaceous*). At stream's edge, a wide variety of plants flourish including Rocky Mountain maple (*Acer glabrum*), gray alder (*Alnus incana*) , common snowberry (*Symphoricarpos albus*), red osier dogwood (*Cornus stolonifera*), twisted stalk (*Streptopus amplexifolius*), sweet-scented bedstraw (*Galium triflorum*), western meadowrue (*Thalictrum occidentale*), mountain bluebells (*Mertensia ciliata*) and fowl mannagrass (*Glyceria striata*). Plants of the compositeae, rancunculaceae, liliaceae, rosaceae and graminaceae families comprise over 50% of the species in the riparian plots (Table 1). The shrubs and small trees in most of these plots create a dense, tangled undergrowth that is difficult to walk through.

Plants with constancy make up a relatively small portion of these plots (29-44%, Appendix C) because this environment contains most of the rarer species in the RNA. Weedy invaders of the riparian area include common mullen (*Verbascum thapsus*) and common dandelion (*Taraxacum officianale*).

Two plots exhibit such unique characteristics that they do not group well during cluster analysis. Plot 25 consists almost entirely of talus. Only a few shrubs (i.e. mock orange and serviceberry) survive in this harsh environment. Plot 25 also exhibits a very high percentage of weedy species (33%) because it is adjacent to a road. Plot 25 always clusters with the riparian plots no matter what type of cluster analysis is specified. Both environments contain hot, dry, inhospitable talus so the grouping based on talus is not surprising. However, the plot has little vegetation in common with the very diverse riparian plots. Plot 1 also reflects a unique microclimate. Plot 1 is in a mixed-savannah community with very large, abundant Rocky Mountain junipers shading most of the plot. Therefore, the flora reflects both a hot, dry grassland habitat (i.e. arrowleaf balsamroot, rabbitbrush and Idaho fescue) with the more shaded, canyon forest habitat (i.e. common snowberry and ponderosa pine). Plot 1 is also unique because it contains abundant bare ground with virtually no grass except for minor cover of rough fescue plants. 14% of its total species are "weedy", including abundant spotted knapweed, pale alyssum and sulphur cinquefoil.

Species diversity is compared for the five communities in Figure 4. The highest Shannon-Weaver diversity (H'), richness and evenness is found in the riparian forest. Mean values are 41.8, .96, and 3.74%, respectively. The high diversity index for the riparian community (H'=3.74) reflects a combination of xeric and mesic species in the plots. Plot 25, a riparian plot outlier, contains only nine species and is obviously quite different than the other riparian forest plots (Figure 4). The sagebrush-savannah community possesses almost the same richness (mean = 48 species), diversity (mean 3.66) and variability (mean evenness=.95)as the riparian forests. Lowest in richness, diversity and evenness is the canyon forest. The mean Shannon-Weaver diversity index (H') for forests is 3.23. The extreme range in evenness (i.e. .89 to .96) in the forest plots reflects a combination of open and closed forest plots in the analysis, as well as different environmental conditions within each plot.

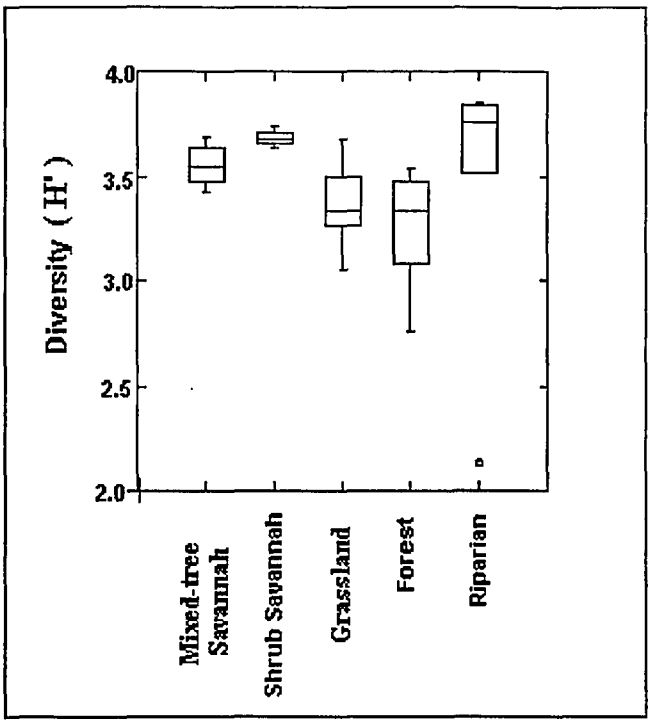


Figure 4: **Ranges in Shannon-Weaver diversity index (H') by community, Sawmill Creek RNA**

Table 2 shows the distribution frequency of annual, biennial and perennial species in the RNA study plots. Comparison of the study plots by habitat shows that the grassland and mixed-savannah plots possess the highest percentages of annual species in the RNA (14-33%), mainly in the composite, cruciferae, graminaceae and scrophulariaceae families. The riparian plots contain the highest percentage of biennial and perennial species (80-95%) and the lowest percentage of annuals (2-14%).

Figure 5 shows the average percentage of natural and weedy species in each community. Grassland and mixed-savannah plots contain the greatest percentage of weedy species (7-32% of total species in plot). Riparian and canyon forest plots are relatively weed-free (0-10%). Mean percentages for the riparian plots are calculated without plot 25, which contains over 33% weeds. Plot 25 consists almost entirely of talus and is located close to a road not the creek. Appendix D shows the variation in percentage of weed species by plot.

Table 2: **Mean number of species by life cycle**

		# Species							
	# Plots	Annual	Std. dev.	Biennial	Std. dev.	Perennial	Std. dev.	Total	Std. dev.
Grassland	9	9.8	2.5	1.9	0.3	25.2	7.0	36.9	7.4
Sav. Shrub	3	7.7	0.6	2.3	0.6	38.3	3.2	48.3	3.2
Mixed Sav	11	9.5	2.3	1.9	0.9	31.4	3.9	42.7	4.2
Forest	5	4.4	2.4	0.2	0.4	28.4	6.1	33.0	8.0
Riparian	5	3.4	1.9	2.8	1.3	35.6	18.9	41.8	19.2

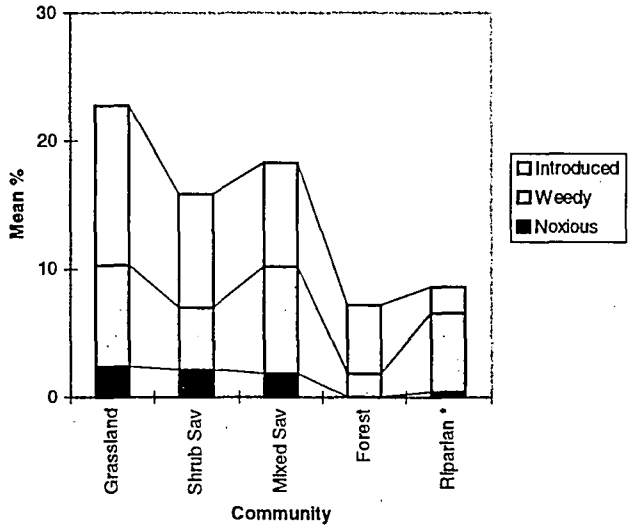


Figure 5: Mean percent of weedy and introduced species by community (Origin mainly after Lackschewitz, 1991)

Factors controlling vegetation in RNA

Indirect ordination suggests that the controlling factor for composition of the communities in the RNA is potential evapotranspiration. In the past, overall climate and disturbance, such as fire and grazing, controlled the composition of these communities. Today, the controls are mainly physiological and related to current physical characteristics of the site.

Axis 1 is the strongest axis in detrended correspondence analysis (DCA) for this study (eigen value=.619). It is bounded by plots 6 and 28 (Figure 4). Plot 6 consists of typical grassland species, such as Rocky Mountain juniper, big sagebrush, arrowleaf balsamroot, fringed sagewort (*Artemesia frigida*)

and many species of grasses. Plot 28 is a riparian plot containing gray alder, Rocky Mountain maple, Bebb's willow (*Salix bebbiana*), Cascade mountain ash (*Sorbus scopulina*), thimbleberry (*Rubus parviflorus*), mountain wood fern (*Dryoteris austriaca*), sweet-scented bedstraw, twisted stalk, yellow monkey flower (*Mimulus guttatus*) and fowl mannagrass.

Axis 1 appears influenced by a combination of environmental factors that control potential evapotranspiration. One factor is the amount of protection the plot gets from intense sunlight. All of the very open plots that lack protection from intense sunlight are located on the far left of axis 1. Grading to the right are those in partial shade or shade for part of the day (middle graph) to those in very protected, shaded plots with abundant overstory cover. Another factor that controls potential evapotranspiration is proximity Sawmill Creek and intermittent water sources in the RNA. All plots located close to a constant water supply plot to the far right of axis 1 except for Plots 1 and 27. Plot 1 is located fairly close to Sawmill Creek, contains junipers for some shade, but receives intense, hot, southern exposure sunlight on a fairly steep slope. Therefore, it has very high evaporation and plots closer to the dry, grassland plots than those near riparian areas. The same is true for plot 27 except this plot contains no overstory for shade. Plot 25 (Figure 6) is an anomalous plot consisting almost entirely of talus that is located in a protected drainage that is shaded part of the day. Other factors that control soil moisture and potential evapotranspiration are slope and the presence of roots or coarse woody debris to slow runoff. Most plots to the left on axis 1 (Figure 6) are located on steep terrain (>20 degrees) and have few roots or coarse woody debris to slow runoff unlike plots from the forest and riparian areas.

The second strongest influence on the ordination is axis 2 (eigen value=.207). The extremes on axis 2 are plots 3 and 30 (Figure 6). Plot 3 is a west-facing sagebrush savannah dominated by drought-tolerant plants, including big sagebrush, lupine (*Lupinus spp.*), rosy pussytoes, sulphur buckwheat (*Eriogonum umbellatum*), twin-leaved owl clover and several types of grasses. Plot 30 is a south-facing riparian plot that is further from the river than plot 28 described above. Plot 30 is dominated by chokecherry, mock orange, ninebark, red osier dogwood, red raspberry (*Rubus idaeus*), gooseberry (*Ribes lacustre*) and currants (*Ribes sp.*).

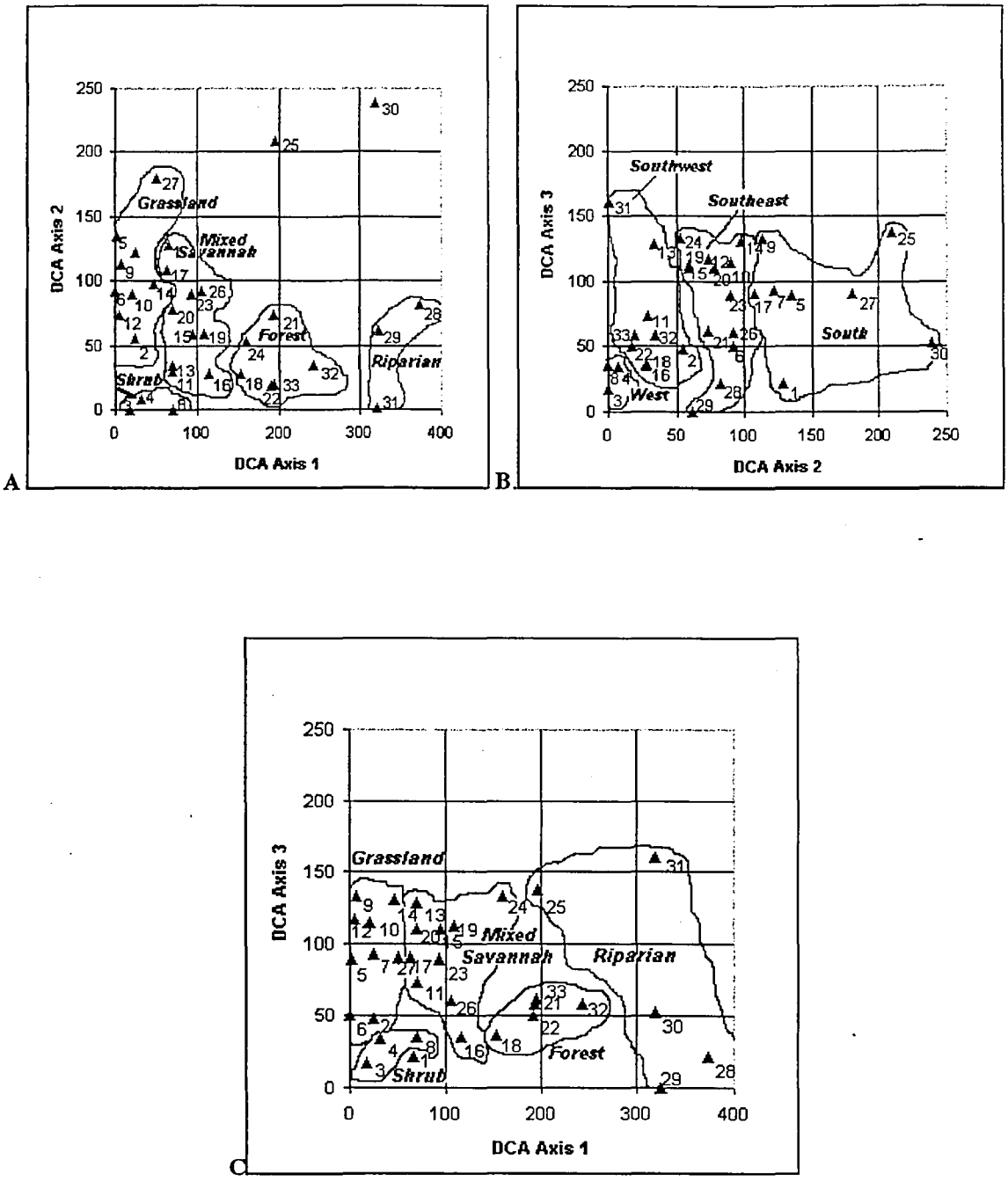


Figure 6: **Detrended correspondence analysis (DCA) ordination using all 184 species identified in plots.**

Axis 2 appeared controlled by a combination of aspect and/or duration and intensity of sunlight. West-facing plots are located on the far left of the diagram (Figure 6). South-facing plots are to the far right. Southeast- and southwest-facing plots are intermediate. Those plots that do not fit exactly in this pattern, such as Plot 15, 20 and 24 (all southern exposures) and Plot 21 (western exposure), are located in mountain shadow areas or steep drainages, which protect from direct sunlight.

DCA axis 3, which is the weakest influence (eigen value=.174), is limited by plots 31 and 29 (Figure 6). Both plots are riparian plots. One is southwest facing (31); one is southeast facing (29). Both contain many of the rarer riparian species in the RNA (twin flower (*Linnaea borealis*), twisted stalk, wartberry or fairy bells(*Disporum trachycarpum*), western meadowrue). Both contain many tree species (Douglas-fir, ponderosa pine, Rocky mountain maple). Plot 31 has gray alder (*Alnus incana*); plot 29 has Bebb's willow. Both contain many shrubs (chokecherry, common snowberry, mock orange, ninebark, dogwood, serviceberry, white spirea (*Spirea betulifolia*), currents and gooseberries). Plot 29 contains abundant oregon grape (*Berberis repens*); plot 31 contains abundant gooseberries. Both contain similar herbs from wet and dry habitats; including, mountain bluebells (*Mertensia ciliata*), mountain wood fern (*Dryopteris austriaca*), sweet-scented bedstraw (*Galium triflorum*), white bog orchid (*Habenaria dilatata*), twinflower (*Linaea borealis*). Both plots have abundant horsetail and scouring rush (*Equisetum arvnse* and *E. hymale*). Plot 29 has abundant mountain bluebells, showy aster (*Aster conspicuus*), and mountain wood fern.

Axis 3 may be controlled by soil temperature affected by change in life form and aspect. Within each grouping from left to right, the plots are arranged from those plots containing the most near-ground coverage of shrubs and/or small trees receiving more indirect sunlight (lower axis 3) to plots containing soil that is very exposed to direct sunlight for most of the day and have almost no vegetative cover to shade the soil (upper axis 3).

Structure

Basal area analysis supports the hypothesis that the structure of the forests and grasslands have changed from historic conditions towards increased composition of Douglas-fir. Although, Ponderosa pine no longer dominates the composition of forest plots as it did in historic times, it is still the main tree

species in the open areas of grassland, mixed-tree savannah and shrub savannah of the RNA (Table 3). Table 3 shows that Douglas-fir now dominates basal area in both forest (mean=56%) and in riparian plots (mean=72%). Figure 7 shows a comparison between basal area of trees in RNA study plot 18 and basal area of trees in a similar forest in Pattee Canyon. Plot 18 is a typical RNA forest plot that faces S50°W and is located in the bottom of a moist ravine. Like Habeck's (1994) north-slope habitat types, plot 18 keys to the Douglas-fir/ninebark habitat type. However, it keys to the pinegrass (*Calamagrostis rubescens)* phase instead of Habeck's *Physocarpus malvaceous* phase. Figure 7 shows that Douglas-fir dominates the basal area of the RNA forest similar to Pattee Canyon. Because Sawmill Creek contains Rocky Mountain juniper, not abundant larch (*Larix occidentales*), the proportions are not completely analogous. However, the trends are unmistakable. Figure 7 also shows the substantial increase in Douglas-fir from pre-settlement conditions to current day in both Pattee Canyon and Sawmill Creek RNA.

Table 3: Mean basal area of tree species in five RNA communities

Community	Total # Plots	Mean BA Douglas-fir	Mean BA P.pine	Mean BA Juniper
		m^2/ha	m^2/ha	m^2/ha
Grassland	9	0.15	0.94	0.05
Mixed Savannah	11	2.2	5.31	0.3
Shrub Savannah	3	0	0.3	0
Forest	5	15.1	11.68	0
Riparian	5	6.32	2.4	0

Not only does Douglas-fir dominate the forest plots, it is also most abundant on riparian plots (Table 3). One or two very large, old-growth trees accounted for most of the ponderosa pine basal area in Table 3. The Douglas-fir basal area, however, averaged 72% of riparian plots and encompassed several mid-size (30-50 dbh) trees in each plot.

The grassland-dominant communities possessed very small basal areas of Douglas-fir and Rocky Mountain juniper (Table 3). Table 3, however, does not completely show the degree of cover on the grasslands by these tree species. Figure 8 shows the abundance of juniper and Douglas-fir trees on the

grassland. Some of the discrepancy was a classification problem. Plots that contained several trees and/or shrubs did not classify as grasslands in cluster analysis or in field classification. They classify as mixed-tree savannah . Another problem was that the small plots used in this study often missed the widely-scattered trees and shrubs. In addition, shrubs were not measured for basal area. They were measured only using visual estimates of percent cover in each plot and results varied with the location of the study plot on the landscape (see Appendix B). Therefore, Table 3 probably underestimates the basal area in the grassland community.

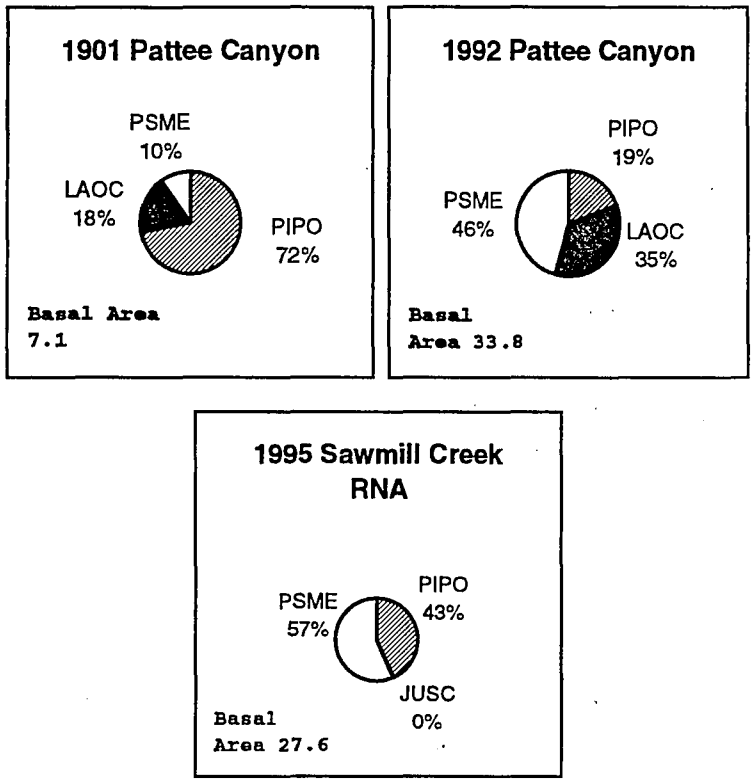


Figure 7: Basal area comparisons between RNA and Habeck (1994) Pattee Canyon study. Sawmill Creek = Plot 18.

Figure 8: Rocky Mountain juniper and Douglas-fir encroachment on grassland, Sawmill Creek RNA.

Percent cover analysis also shows that the relative dominance of tree species has changed considerably from historic proportions. Douglas-fir comprises 65% of all trees sampled in the RNA. Ponderosa pine and rocky mountain juniper comprise 28% and 7%, respectively. Figure 9 shows the average number of trees in each community. Douglas-fir dominates all communities except the grassland. The size-class distribution within these communities is shown in Figure 10. Figure 10 highlights the fact that Douglas-fir is not only the most abundant tree in the sample plots, but it also dominated most size classes (Figure 10). Only in the very large size classes (>50 cm dbh) did ponderosa pine outnumber Douglas-fir, and the number of trees of both species in these size classes was very small (Figure 10).

The number of ponderosa pine in each size class varied widely in the open, dry savannah and canyon forest environments. The number predictably declined, however, in both habitats as trees get older. Figure 10 also shows that the number of ponderosa pine has remained constant in recent years (i.e. 5-9 cm dbh). This result is deceiving, however, because most plots actually showed a decrease in ponderosa pines

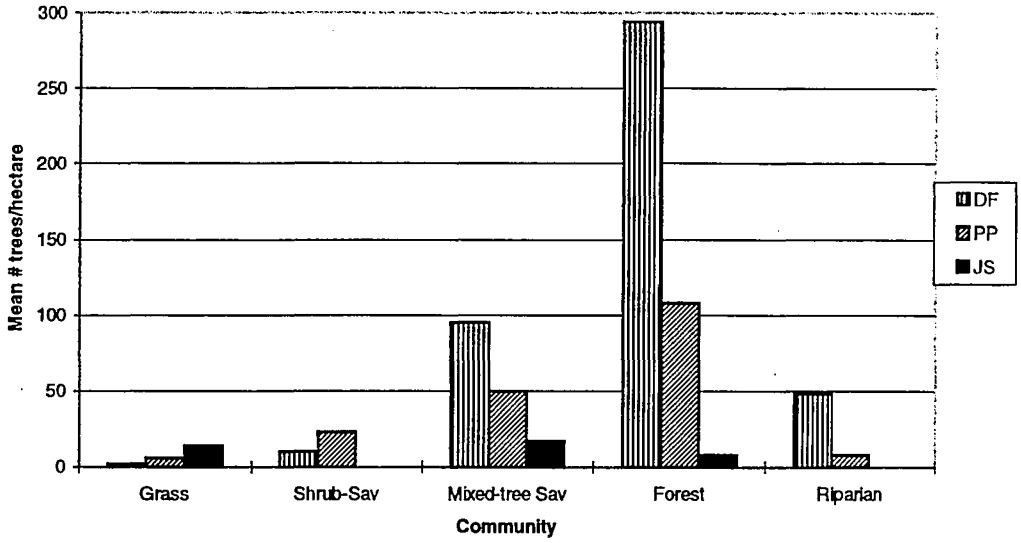


***Figure 9*: Average number of overstory trees by community, Sawmill Creek RNA. Community designations based on cluster analysis results.**

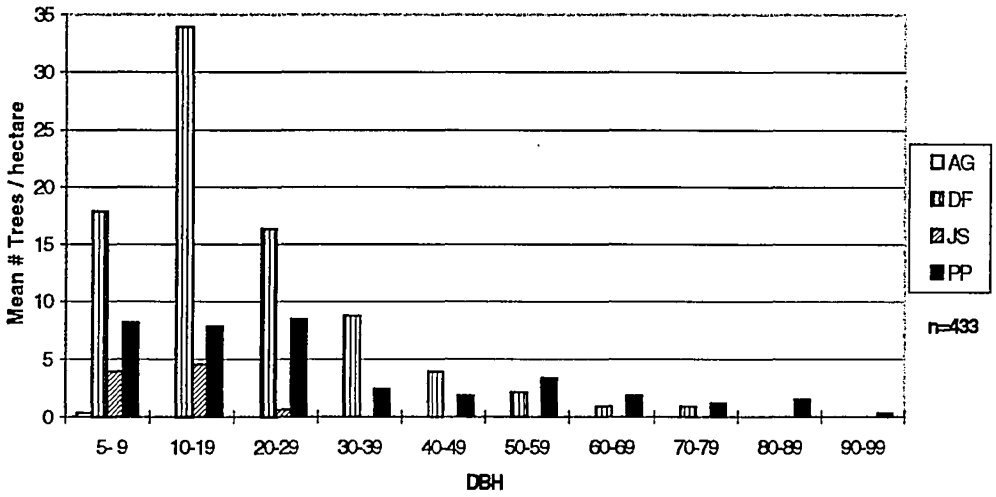


***Figure 10*: Size class distribution of overstory trees, Sawmill Creek RNA**

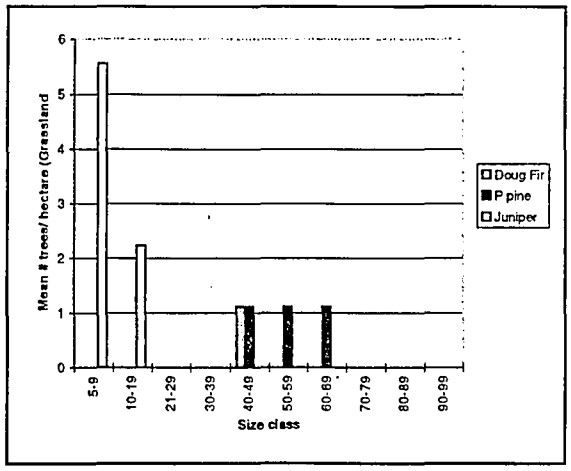
in this size class (Figure 11). The increase is explained by plot 19, which is a mixed-savannah plot. In plot 19, a small, residual grove of ponderosa pine remained untouched when the area was logged. This

plot contained 12 of the 18 trees recorded in the 5-9 dbh size class in the 11 plots. Therefore, Figure 10 falsely indicates that ponderosa pines flourished under recent conditions in the RNA. In reality, only one or two trees, if any, in this size class existed on most plots and the survival of trees in this size class was, in general, poor in the RNA.

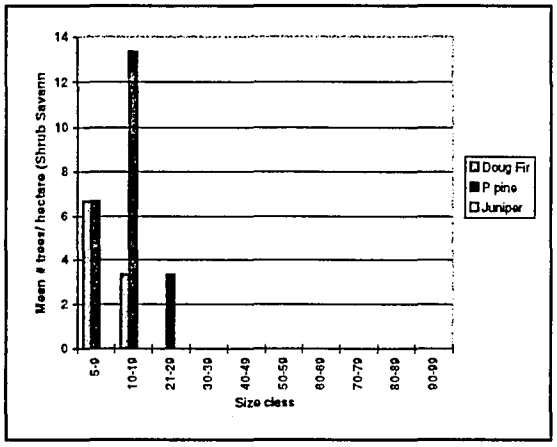
Rocky Mountain juniper, which is a relatively long-lived tree found almost exclusively on the grasslands and savannah of the RNA, appeared also to have increased in numbers over time in the canyon forest based on increased numbers in the lower size classes (Figure 11). However, the age of these small diameter trees was not examined to determine if they are only recently increasing or if they were fairly old. Counting these trees was also difficult. They often grew in concentrated, dense clumps with several stems each that looked like, and affected their environment like, a single tree. Therefore, the counts in the lower size classes were probably underestimated.

Douglas-fir showed substantial increase in trees in the mid- and lower size classes (<30 cm dbh) in all communities except the grassland (Figure 11). The quantity of Douglas-fir trees in the savannah showed the most pronounced recent change. In these partially sheltered areas, shrubs and/or ponderosa pines shaded germinating seedlings. As a result, numbers of Douglas-fir exploded in the mixed-savannah areas in the past 50-75 years (<30 cm dbh, Appendix E). In the forest, the influx of Douglas-fir started about 100 years ago (Figure 11). Appendix E shows that Douglas-fir with >40 dbh in the forests are over 100 years old. In the riparian area, the mean number of Douglas-fir trees rose slightly in the last 150 years (Appendix E, df<75 cm dbh = 150 years).. The decline in numbers of both Douglas-fir and ponderosa pine from the 10-19 size class to the 5-9 size class in most habitats is addressed later in this section with regeneration and health problems in the RNA.

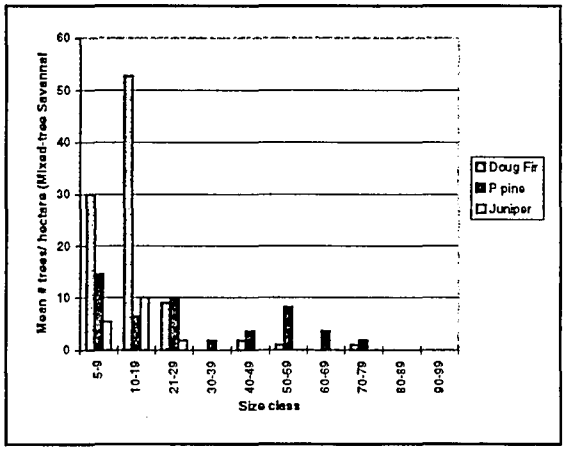
The relationship between size and age in the RNA for ponderosa pine and Douglas-fir is given in Figures ##and ##. There are distinct differences in ages between species at the various sizes. There are also differences in ages at the same relative size corresponding to community. For example, at the 70 dbh class, ponderosa pine is approximately 100 years old in the mixed savannah but over 125-150 years



A. Grassland

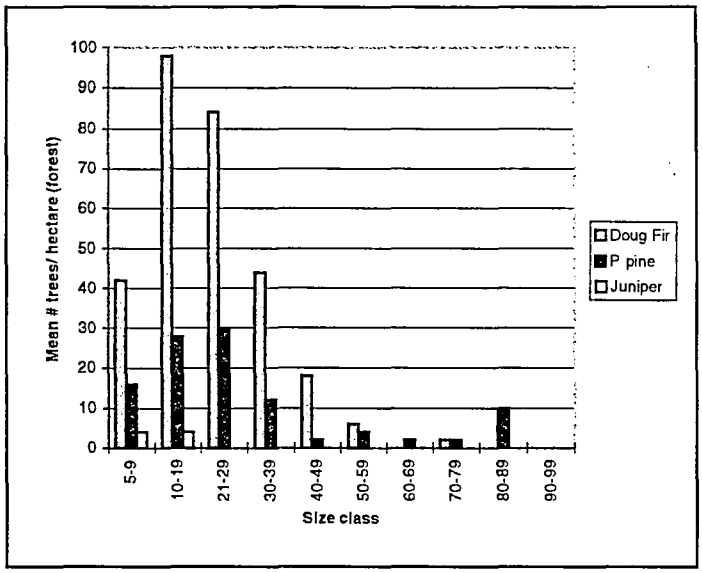


B. Shrub Savannah

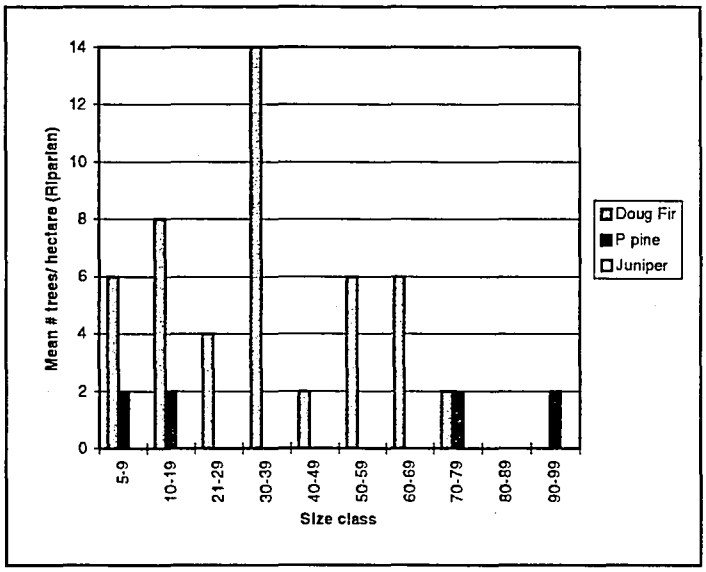


C. Mixed-tree Savannah

***Figure 11*: Size-class distribution of overstory trees by habitat, Sawmill Creek RNA**



D. Forest



E. Riparian

***Figure 11 (cont.)*: Size-class distribution of overstory trees by habitat, Sawmill Creek RNA (a) grassland; (b) shrub savannah; (c) mixed-tree savannah; (d) forest; (e) riparian.**

old in the riparian environment (Figure 12). These differences are expected due to the differences in light, physical conditions, and competition between these two environments. Similar differences occur within a single community for both ponderosa pine (Figure 12) and Douglas fir (Figure 13). Within the 50-55 size class, Douglas-fir varied from 100-125 years old; 45-50 dbh ponderosa pine varied from 120-160 within the canyon forest. depending on growing conditions.

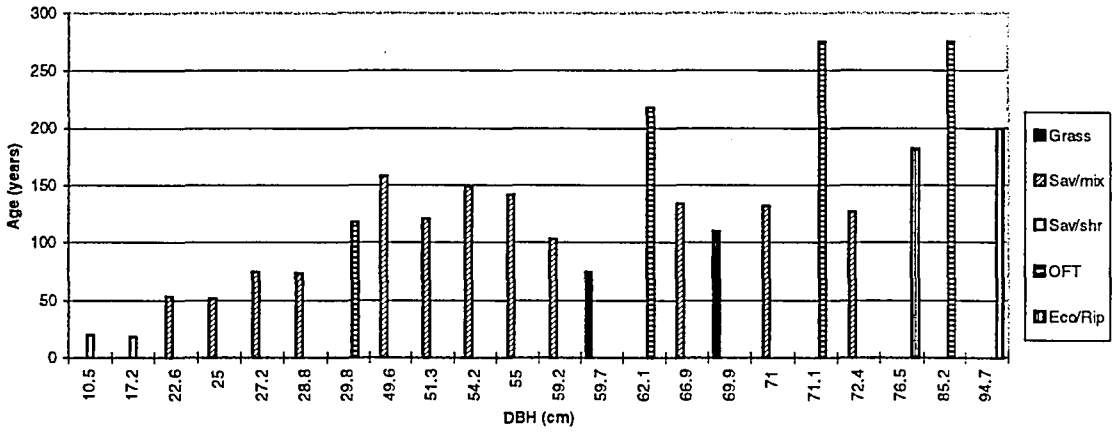


Figure 12: Ponderosa pine size versus age by community

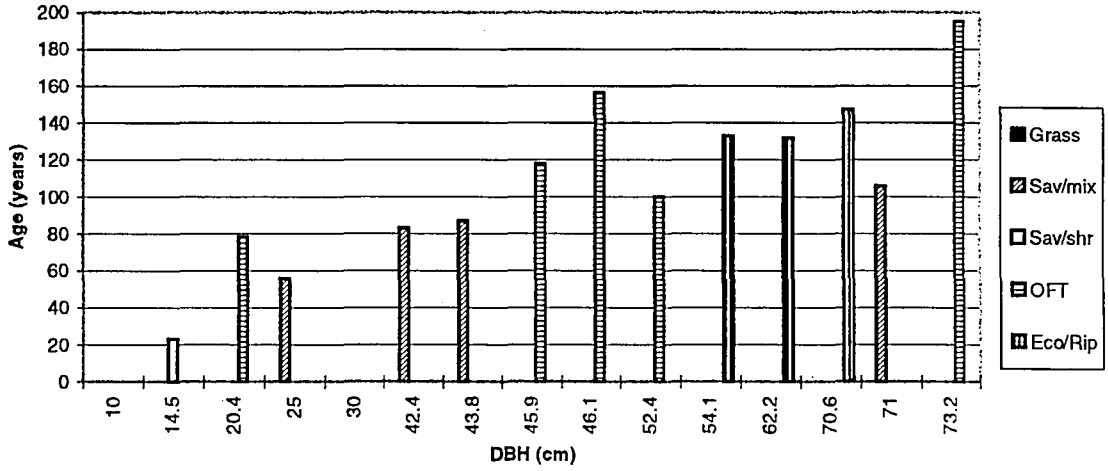


Figure 13: Douglas-fir size versus age by community

Cores taken from select trees not only show the age distribution of each size class, they also show that growth conditions varied in the RNA forests during the past 200 years. The cores of both ponderosa pine and Douglas-fir exhibit very tightly-packed growth rings at several intervals along the core, indicating environmental stress of some type (i.e. drought) in the tree's history. The cores exhibit tight patterns at approximately 50 years ago (duration 10-20 years), 80-90 years ago (duration approx. 5 years), and 110-130 years ago (duration 7-8 years). Aoppendix L shows the distribution of tight growth-ring patterns through time. Many of the ponderosa pine cored show a tight-ring pattern for the past 10 years. However, few sampled Douglas-fir showed a similar pattern. Seedlings with shallow, undeveloped root systems have a high percentage of mortality for both ponderosa pine and Douglas-fir and may be drought-stressed. Other causes for the mortality (i.e. grazing) are examined in a later section of this paper.

Tree growth in the last 10 years varied with habitat and with species. Those trees growing isolated in the mixed-savannah habitat had little competition for water, light and nutrients and added girth at approximately 2 mm/year (Appendix E). The mean 10-year increment for Douglas-fir in the savannah habit was 22.9 mm; for ponderosa pine, 14.43 mm. Those trees growing in the canyon forest and riparian habitats added girth, in general, at less than 1 mm per year. The mean 10-year increments for the riparian area were 13 mm and 7 mm for Douglas-fir and ponderosa pine, respectively. Trees growing in the canyon forests of the RNA had a mean 10-year increment of 8.8 for Douglas-fir and 6.5 for ponderosa pine. A partial core of juniper (17.6 dbh) resulted in an increment for the last 10 years of 14 mm. Old-growth ponderosa pine and Douglas-fir grew less than 1 mm per year.

Analysis of vigor class of ponderosa pine trees in the RNA supports the hypothesis that their growth is stressed in some communities and that their structure is unlike historic ponderosa pine. Ponderosa pines growing in the open savannah, in general, showed good vigor (i.e. "1A" and "1B" classification) with thick, pyramidal crowns (Figure 14). The boles were straight and tall, with few dead or dying lower branches. They were the most like historic ponderosa pines because they grew in open environments. Trees in forest habitats, on the other hand, had the worst vigor. Most were classified as "C"and "D" (Figure 14). These trees grew under stressful conditions during some part of their life and

formed dead or deformed crowns and abundant dead lower branches (Keen, 1943). Ponderosa pines in the riparian area, like the forests, had mostly sparse, straggly crowns on both young and old trees and were classified "1C" to "2D".

Vigor designations also related to tree age. Trees that were greater than 60 cm dbh in the RNA were classified as "old-growth" because all of their core bores showed them to be over 200 years old (Appendix F). Old-growth ponderosa pines that are growing in an canyon forest habitat had mostly "C" and "D" vigor classifications (Figure 15). Old-growth trees in the savannah faired much better with mostly "1A" designations. Young trees (i.e. those with small dbh) varied considerably from very good

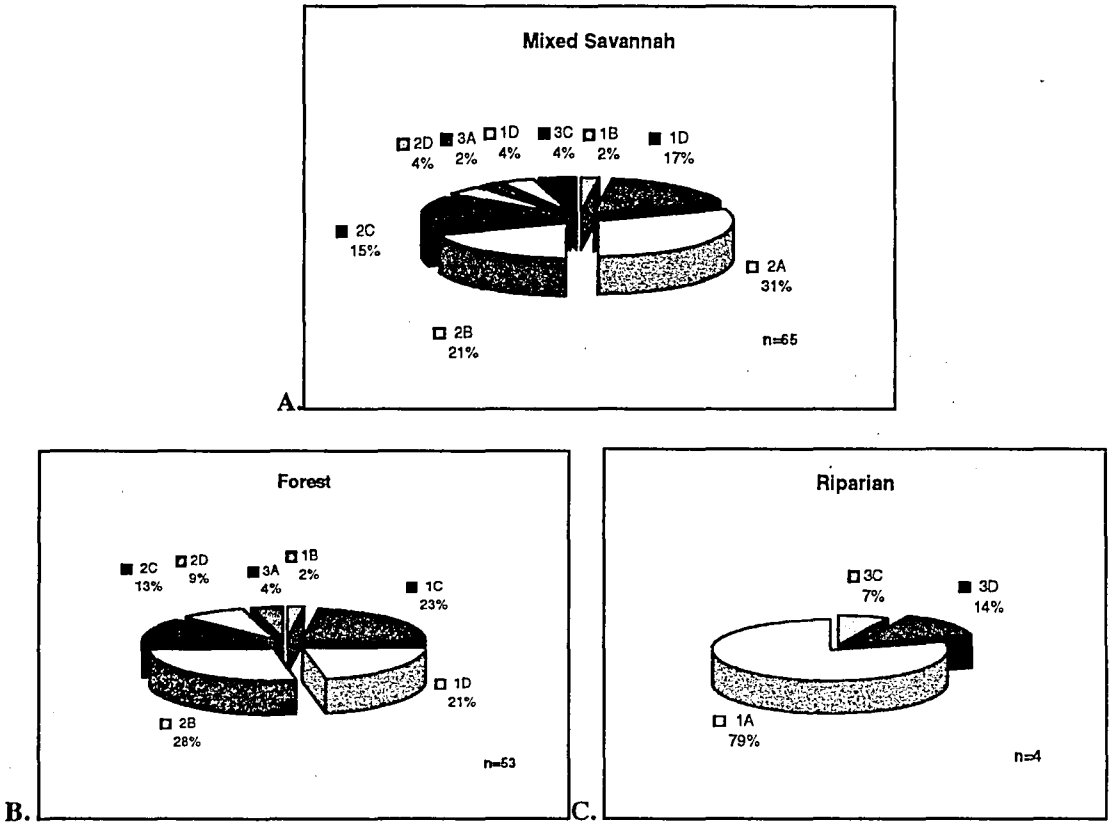


***Figure 14*: Ponderosa pine vigor designations by environment, Sawmill Creek RNA.**

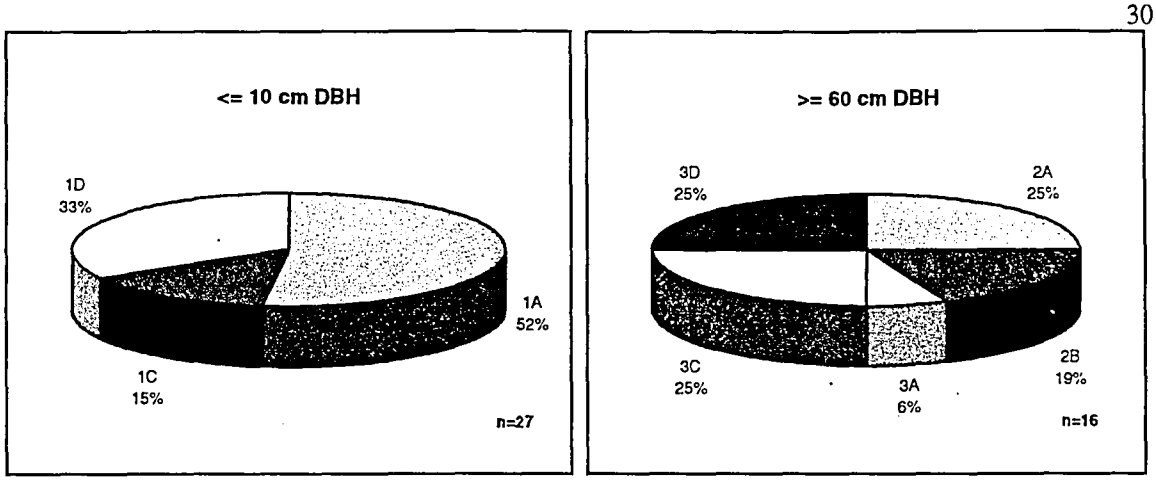


Figure 15: Ponderosa pine vigor designations by age, Sawmill Creek RNA.

vigor (1A) to fairly poor vigor ("3D") in all environments. They were almost equally split between healthy, robust crowns and thin, sparse crowns with dead lower branches (Figure 15).

Evidence suggests that some natural disturbance regimes are currently operating in the RNA to degrade target communities. These disturbances are documented only with photographs for this study and include insect and disease infestations, grazing, and wind throw. They directly affect growth and production and endanger the long-term survival of the conifer and bunchgrass communities. Insects infestation is common in ponderosa pine cones. Insects bore into the cone, destroy the seeds and create deformed cones (Figure 16). Cone destruction is similar to that caused by cone worms (*Dioryctria spp* or *Eucosma spp.*). For the past few years, local foresters have had difficulty locating good cones for the historic seed bank collections (Curry, personal communication). These cone-boring insects may be a partial source of the problem. Second, Douglas-fir trees exhibit severely deformed, broom-like growth in their branches. They are probably infected by mistletoe. Many of the infected Douglas-fir trees are near the riparian area and in the central and eastern drainages. Third, mountain maple showed signs of a severe red viral infection on its leaves. Serviceberry bushes also exhibited signs of a viral or fungal infection that creates brown and rust spots on the leaves. A forest pathologist is needed in the RNA to access the extent of these health problems quantitatively before damage to the trees becomes too severe and the regeneration of the forests is endangered.

Figure 16: **Ponderosa pine cones with insect borings and deformed growth, Sawmill Creek RNA.**

Several ponderosa pine and Douglas-fir seedlings appeared to be stressed or killed by grazing (Figure 17a, plot 26) and/or winter drought. In addition, many of the shrubs and bunchgrasses showed signs of extensive grazing (Figure 17b, plot 21). An increase in the population of grazing ungulates over the past few years would cause low regeneration and the decline in the 5-9 cm dbh size class in the study plots mentioned earlier (Figure 11). Many of these lower size classes of ponderosa pine, especially in the forest areas, showed deformed crowns (vigor classes "c" and "d") that would be consistent with growth stress caused by grazing the young trees. Other Douglas-fir and ponderosa pine seedlings exhibit characteristics common of winter drought injury. The small trees show no signs of grazing, but have all or part of the tree dead.

Evidence supports the hypothesis that coarse woody debris accumulated on forest and savannah floors in the absence of frequent ground fire and that this accumulation places some communities at risk of catastrophic fire. The RNA contains both areas of natural accumulation of woody debris from deadfall and windthrow and areas of accumulation from past logging in the RNA. Over 138 million cubic centimeters of coarse woody debris (dwd) was measured and categorized from the study plots. This debris

A. B.

Figure 17a: Severely browsed seedling trees common in Sawmill Creek RNA.
Figure 17b: Well-browsed bunchgrass colonies, Sawmill Creek RNA.

included boles and branches lying on the ground, stumps near the ground, and snags standing in the savannah and forest areas.

As with plant composition and vigor, quantity and condition of coarse woody debris varied considerably between the plant communities (Figure 18). The open-forest, riparian, and mixed-savannah contained 27%, 9% and 63% of the total dwd, respectively. The **forests** contained coarse woody debris mainly in Class 4 and 5. The **riparian** areas contained Classes 2, 3, and 4. The riparian areas also contained an abundance of dwd that was less than 5 cm dbh. This small-diameter debris was not measured for this study but would dramatically increase fuel load in the RNA if it was measured. Most of the coarse woody debris in this community was concentrated at the base of the steep forested slopes where these slopes interface with the riparian area. The **mixed-savannah** plots contained mainly Class 3 and 4. Stumps were common in the mixed-savannah areas (Figure 18). Some of the stumps were created during past logging of the RNA from very large ponderosa pines that reached up to 90 cm in diameter. Most of these stumps were in decay Class 3 and 4. Evidence of very recent tree cutting was found in both savannah and forest plots (i.e. plots 17 and 33). Class 1 dwd existed in both plots and Plot 33 contained a Class 1 stump with recent saw marks and sawdust. In the protected RNA, evidence of recent dwd is cause for concern.

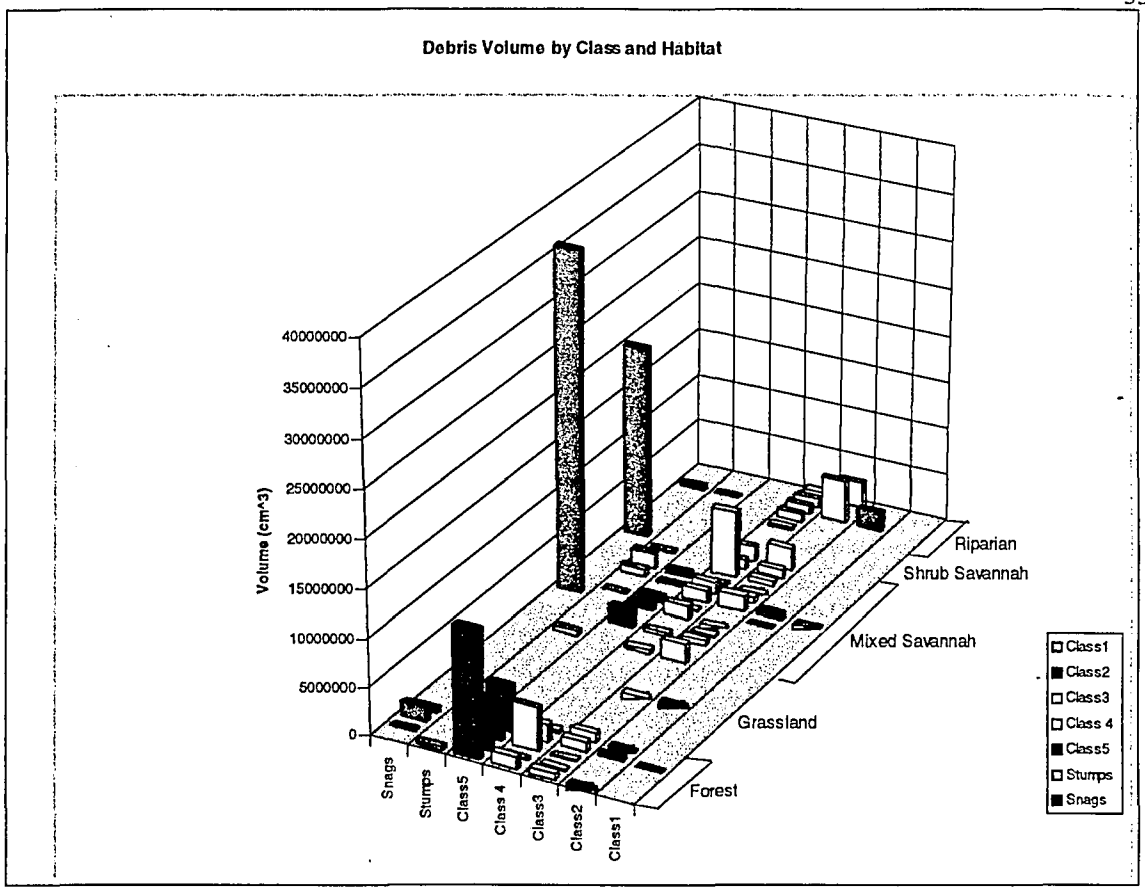


Figure 18: Coarse woody debris by type, decay condition and habitat, Sawmill Creek RNA.

Discussion

The most immediate problem in the grassland and mix-tree savannah communities is the high proportion of weed species in the study plots. Weedy, invasive species, such as spotted knapweed, dalmation toadflax, sulphur cinquefoil, cheatgrass, and St. John's wort threaten the growth and reproduction of native grass and herbs. Results from this study indicate that plants not native to the Bitterroot Mountains comprise up to 20% of the species in a grassland or mixed-tree savannah plot. Therefore, immediate control of these species is essential to long-term survival of the native bunchgrasses and herbs of the RNA.

Another problem of major concern is the successional change in these conifer/bunchgrass communities from historical open, ponderosa pine forests toward a Douglas-fir climax series. Several lines of evidence in this study show that this shift has occurred in the RNA. Basal area, percent cover,

vigor class and coarse woody debris accumulation all show a trend away from historical conditions that characterized these communities in the past. Outside the RNA, such shifts in composition and structure would be considered normal processes and not worth concern. They would be controlled by logging to imitate fire processes or by natural fire ignitions, or they would be left in natural state to progress to the climax series. However, the purpose of the RNA is to maintain the conifer/bunchgrass communities into perpetuity. If these communities change successional state, future generations lose either the trees typical of these forests or they lose the grass species under these trees. In either case, the RNA fails to meet mandates to maintain these rare communities for future education, research and enjoyment.

The only natural disturbance lacking in the RNA was the natural process of fire. Evidence of insect and disease, grazing and windthrow was all present. Evidence of fire was also found but only in a small patch of forest that burned within a short time frame. There was no evidence of the widespread, low-intensity ground fires common to the historical Rocky Mountain west. Nor would such evidence be expected because the National Forest Service policy of fire suppression has been in effect for over 60 years. Most of the evidence of fire that was found during this study was linked to logging and slash-and-burn policy or recreational campfires, which occurred before RNA establishment.

Excluding the natural process of fire from the forests and the grasslands is probably the singlemost important factor responsible for the change in composition and structure on the RNA from historic times. Frequent low-intensity ground fires historically curbed Douglas-fir regeneration (Habeck, 1994). Numerous Douglas-fir trees create forest health problems because they effectively compete for limited resources in the forest (Harrington, 1996). Fires also cleansed the forest floor of accumulated deadfall and debris and recycled vital nutrients to the soil. They controlled availability of material for insect and disease infestation.

Overgrazing is the second-most important factor governing composition and structure in the RNA grasslands and forests today. Unlike in historic grasslands, domestic cattle are not the problem on the RNA. In fact, the RNA received very little cattle grazing in the past. It was historically used as spring pasture for government pack and saddle horses, but "timing and intensity of grazing was closely monitored" and controlled (Habeck, 1992). Therefore, its bunchgrass communities remained in good

enough condition to justify RNA establishment (Habeck, 1992). Today, the RNA is being overgrazed by native wildlife. Bunchgrass plants had heads and stems sheared off before seed for new plants were produced or the perennial rootstocks were nourished. Tree seedlings were in marginal condition or dead in many areas of the RNA. It is well-known fact that mule deer and whitetail deer browse conifer trees when other food sources are scarce. Their eating preferences are detrimental to the growth and production of the bunchgrass plants and to the conifer seedlings required for forest regeneration. According to Caldwell and others (1987), when bluebunch wheatgrass and crested wheatgrass are removed from spaces shared with big sagebrush, phosphorus acquisition by the sagebrush increases up to six times within two weeks of defoliation (i.e. 85% grass removed). Removing this grass canopy, therefore, rapidly modifies resource competition in favor of sagebrush (Bedunah, 1992). The population of native deer will have to be controlled on the RNA to protect the resource competition and ensure long-term survival of the target communities.

Chapter 2: Landscape Analysis

Introduction

The objective of landscape analysis is to determine how landscape changes affect the vegetation targeted for protection within Sawmill Creek.. Changes in patch size and canopy density are quantified to show relative changes that occurred both within the RNA and in the surrounding landscape between 1937 and 1993. The 56-year period analyzed for this study was a time of human population growth, increased use of the national forests for recreation and economics, and suppression of natural fire processes in the valley. It is obvious that these anthropogenic changes would affect both the quality and quantity of cover types on the landscape. However, natural successional processes are also important in the valley. The objective of this analysis is to determine the relative importance of both of anthropogenic and successional influences on Sawmill Creek RNA. Landscape analysis also provides a baseline to project landscape trends into the future, assuming that the processes and their interactions affect the landscape in similar ways in the future as they have in the past. The trend of these changes and their expression on the landscape affects current and future floral compositional in the RNA, as well as its use by wildlife and human populations.

Methods

Site description

The landscape area for this study is 25 mi^2 (64.75 km^2) defined by 1993 aerial photographic coverage. The boundaries of the analysis area are from T8N R19W S2 to T8NR19W S26 to T8N R18W S4 to T8N R18W S28 (Figure 19). The area consists of 16000 acres of private land, federal land and the RNA. Private lands contain 7480 acres of ranches and homesteads with grazing land or agricultural areas. The agricultural lands are mainly fallow or currently cultivated fields concentrated in the floodplains of Burnt and Willoughby Creeks. Some private land is owned by outfitters for grazing livestock and accessing federal land for recreation. Federal land consists of Bitterroot National Forest (6,328 acres), Lolo National Forest (1,907 acres) and Sawmill Creek RNA (285 acres). Although Sawmill Creek RNA is a special-use area within the Bitterroot National Forest, it is analyzed separately

from the national forest to compare changes over time within the RNA and between the RNA and the entire landscape. Federal land is important for wildlife habitat, recreation, and logging.

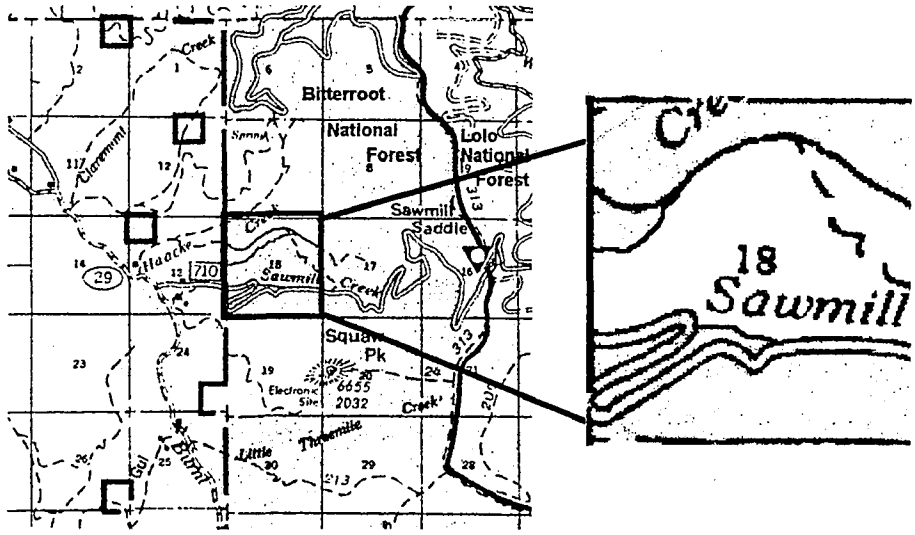


Figure 19: Landscape analysis area (shaded area is federal land; white is private land; Sawmill Creek RNA is white area in expanded diagram of section 18)

Elevations in the landscape analysis area vary from 4600 ft on the west to 7200 ft on the east. The elevations within Sawmill Creek RNA boundaries vary from 4600 ft to 6000 ft. Burnt Creek and its tributaries dissect the western portion of the analysis area and connect it with other physiographic provinces outside the analysis area (Figure 19). Recreation and logging roads also connect the analysis area to outside provinces.

The climate of the Bitterroot Valley is influenced by Pacific air masses from the west coast and, occasionally, by arctic continental air masses from the north and east (Lackschewitz, 1991). The analysis area is located within a large mountain valley extending southward from Missoula, Montana to the Montana-Idaho border. Many parts of this large mountain valley, including the Bitterroot valley and its surrounding mountain ranges, exist in a "rainshadow" created when moisture carried by Pacific air masses is released west of the study area in Washington as the air masses rise over the Cascades and mountains of northern Idaho. Rainfall, therefore, ranges from 13-30 inches per year on these lower elevation mountain slopes (Veseth and Montagne, 1980). Mean annual temperature for the landscape area

is 44.3°F (6.8°C) recorded in Stevensville, Montana (Habeck and others, 1992). Mean January temperature is 22.8°F (-5°C). Mean temperature in July is 65.5°F (18.6°C). Soils have mean annual temperatures of 42-47°F (5-8°C) (Veseth and Montagne, 1980).

The study area lies mainly within four vegetative zones. These include the dry and moist sites of major valleys, and the dry and moist sites of the montane zone (Pfister and others, 1977; Mueggler and Stewart, 1980). The principle vegetation in dry valley sites is bunchgrass habitat types (*Agropyron, Festuca*) or ponderosa pine (*Pinus ponderosa*)/bunchgrass habitat types (Lackschewitz, 1991). Principle vegetation of the mountains consist of habitat types where Douglas-fir (Pseudotsuga menziesii var. glauca), grand fir (Abies grandis) or subalpine fir (Abies lasiocarpa) represent the the potential climax (Lackschewitz, 1991). The far eastern edge of the landscape analysis (i.e. elevation 7200 ft) may contain vegetation of the lower subalpine zone.

The landscape analysis area is located on the slopes of the Sapphire Range, which has a complex geological history. The valley bottoms consists mainly foothills or benchland of the Sunset bench (USFS, 1977). These benches are composed of Tertiary sediments washed out of canyons during the last ice age (Habeck and others, 1992). The mountains of the Sapphire Range are composed of metamorphosed Precambrian sedimentary rocks, primarily quartzite and quartz argillite of the Ravalli Group (Ross and others, 1955). In the southwestern portion of the study area, limestone of the Precambrian Newland Limestone form substantial outcrops. Masses of volcanic rocks, which intrude the Precambrian rocks, are scattered throughout the study area. These volcanic rocks consist of gneissic quartz monzonite and granodiorite from the Cretaceous Idaho Batholith and related masses, and latite, and quartz latite of Tertiary age (Ross and others, 1955).

The Tertiary valley-fill sediments weather to form fairly deep soil horizons. Veseth and Montagne (1980) differentiate several different types of soils that form as a result of weathering of Tertiary valley-fill sediments in western Montana. These soils include Musselshell soils, Cabbart soils, Delpoint series soils, and Abor soils. The soils of the landscape study area best fit the Delpoint series and Abor soils based on the dominant vegetation that these soils support. Both soil series support big sagebrush and several types of grasses, including bluebunch wheatgrass, western wheatgrass, needlegrass,

prairie Junegrass, and blue grama. However, the soils of the landscape area were not investigated in detail either within the RNA or on the landscape to pinpoint soil classification. The hard, fine-grained, metamorphosed sediments of the Belt series argillites and carbonates are fairly resistant to weathering (Veseth and Montagne, 1980). Soils of the Belt series that best fit the landscape area, again based on vegetation, are the Haugan series (Douglas fir or ponderosa pine/ ninebark) and the Sharrott series (Douglas fir/ninebark or pinegrass, and ponderosa pine/snowberry), and the Perma soils, which form on alluvium from mixed-Belt Series rocks. Dominant vegetation on Perma soils include blue-bunch wheatgrass, Idaho fescue, arrowleaf balsamroot, western yarrow, and lupine with some ponderosa pine/snowberry (Veseth and Montagne, 1980).

Vegetation mapping

I mapped 13 of the most distinctive vegetation types to access landscape structural changes from 1937 to 1993. Vegetation types are defined by canopy density using 1937 (scale:**) and 1993 (scale**) aerial photographs. I used five criteria to distinguish 13 cover types These criteria were color, tone, texture, pattern and situation. Appendix G summarizes the definitions I used in this study for each vegetative class. I used "Timber Survey Aid No. 5 Guide for estimating degree of stocking on aerial photographs" (USFS, Portland, Oregon) to define percent cover for canopy density in each classification.

I encountered three main problems in the mapping process. First, lack of color made distinguishing some cover types more difficult on the black and white 1937. I had the most difficulty with the bare rock/talus versus grassland because they looked alike except for color. However, after mapping, I made sure that bare-rock classifications stayed consistent on both maps. When they weren't consistent, I used the clearer, colored photos to assign the cover type. Second, I had one pattern that was difficult to classify in Appendix G. This pattern comprised a substantial portion of both years' photographs and appeared dark gray, flat and felt-like (i.e. fine-grained texture). The texture was similar to the clearcut areas in the 1993 photos, but there were no straight boundaries or other evidence of silvicultural thinning that I required in this study to classify them as "unvegetated, treated". There were no isolated or grouped "dots" indicative of emergent tree crowns to place them in savannah or forest. There was no bare ground

visible to place them in grassland. This pattern is also called "Forest, closed canopy". It is probably younger, even-aged forest. However, because it occurred outside of the RNA I do not have a ground-truth plot for it. In 1993, this "Forest, closed canopy, even-age" cover occurred mainly on federal land and occupied over 1140 acres. Thirdly, I had difficulty precisely marking section boundaries on the 1993 photos to correspond to the boundaries marked on the 1937 photos. In many areas, the corners were located in the middle of closed forest or grassland with no distinguishing landmarks nearby.

Procedure

Initially the mapping project utilized a Bausch and Lomb zoom transfer scope (ZTS), which corrects for parallax distortion directly from photo to map. The ZTS became inoperative shortly into this project, however, so I remapped the vegetation covers using a simple stereoscope and acetate overlays. I used the following steps:

1) **Align stereopairs under stereoscope and overlay photos with acetate sheets.** Distortion and parallax were, hopefully, minimized by working in only the center one-half of each photo. Photo edges were aligned as closely as possible using the following criteria: (a) align major features, such as rivers, drainages and rocky hilltops; (b) align section line points identified on the 1937 photos by US Forest service personnel and pinpointed as closely as possible on the 1995 photos; (c) align other minor, changeable features, such as agricultural fields and roads.
2) **Map differences in vegetation cover on the acetate overlay using criteria established in Appendix G.**
3) **Mark positions of all section corners as closely as possible on acetate overlay.** 1937 section corners were marked on the archival photos by Forest Service personnel. I marked the 1993 corners as close to the 1937 section positions as I could. Many corners didn't have distinct features to orient with, so the 1993 had to be estimated.
4) **Scan completed acetate maps on optical recognition scanner.**
5) **Import scanned images into Photo Shop v. 4.0.** Using marked section corners as guide, capture individual section images and print out at proper scale for 7 1/2 minute quadrangle (1 section = 2.63 inches). I used Corley Gulch and Sawmill Saddle 7 1/2 minute USGS quadrangles as base maps for mapping vegetation boundaries from the aerial photos. (Note: Digitizing the complex map data for a geographic information system (GIS) was beyond the scope of this project.)
6) **Place newly-sized, printed sections under mylar transparency of 7 1/2 minute quadrangle.** Align major features on printed sections with same features on topographic map. This forms a composite map consisting of 25 individual 1 mi^2 sections.
7) **Make corrections.** Recapture section data from original scan if newly-sized sections have major distortion or original section corners are marked incorrectly. Resize and reprint until error is minimized between quadrangle transparency and printed section images.
8) **Overlay final composite map with grid.** Each grid cell equals 2.5 acres. 6400 grid cells (16,000 acres) comprise each map.

9) **Record the vegetation cover comprising the majority of each grid cell.** Vegetation is coded numerically for each map (1937 and 1993), and placed in an EXCEL (Microsoft Corp.) spreadsheet (Appendices F & G). Numerical classifications follow Appendix G.
10) **Code ownership for maps.** Land is classified as private, Bitterroot NF, Lolo NF and Sawmill Creek RNA. Bitterroot NF base maps updated in 1989 are used for ownership designations. No attempt is made to adjust the ownership map to 1937.

Three areas did not align well from the 1937 photos. These included an area near Sawmill Creek; and sections 20 and 21. Two photographs were missing from the 1937 archival set near Sawmill Creek. The gap in stereopairs made boundary matching extremely difficult, so the photos had to be matched as closely as possible working peripherally to the area. Sections 20 and 21 were at edges of photographs and required piecing of multiple edges that were extremely distorted. Section 21, in particular, had an hour-glass shape when the photo edges were matched. Using the topographic mylar overlay, some of this distortion was corrected with hand drafting.

Data Analysis

I used a short BASIC computer program to count and total the grid cell data stored in the EXCEL spreadsheet (Appendix K). The BASIC program assigned an ownership code to each cover type cell. I had four ownership classifications: private, Bitterroot NF, Lolo NF, and Sawmill Creek RNA (Figure 20). Grid cells were counted and classified within the program by cover type and their owner classification. Differences in aerial coverage of cover types between 1937 and 1993 were compared using totals and percent change.

The disparity of mapping scales created some difficulties in comparing change within and outside the RNA. Because the RNA contains a much smaller area than the landscape (285 verses 16000 acres), some changes within the RNA were magnified by small errors in assigning grid cells to a cover type. Multi-cover grid cells were difficult to assign in both the landscape and the RNA, but subjective decisions made more difference to RNA results because each cell is 1% of the total RNA area. A difference of one pixel in 16000 acres had much less effect on the landscape results (i.e. .01% of the total

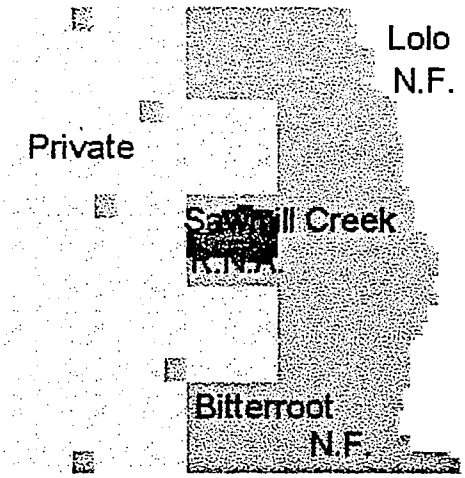


Figure 20: Ownership areas for landscape study area

area). Therefore, changes of one or two percent cover change in the RNA are not significant. A 10% increase in grassland tree cover in the RNA compared to a 1% decrease in the landscape, however, involved a significant number of grid cells at both scales. Therefore, it is probably a valid result that would have significant implications to any restoration plan in the RNA.

I used a paired student t-test to compare the different-sized areas and to determine if there was a significant differences in their means. The paired t-test uses differences between cover types and differences in means to test whether the means between two groups are significantly different. I tested whether the RNA acreage in each cover type were statistically different than any other federal land. I also tested whether the RNA was significantly different than non-RNA (i.e. federal plus private) land. I used the statistical test on two time periods - 1937 and 1993.

Results

Landscape analysis supported the hypothesis that the area of each ecosystem changed over time. In particular, grassland acreage for target vegetation growth reduced dramatically over 55 years by approximately 10% of the total area. Open-forest coverage did not change in mean area, but changed in location on the landscape. Results also supported the hypothesis that the landscape became increasingly

fragmented in 55 years, resulting in reduced corridors for both grassland species and interior forest wildlife species. Fragmentation is defined for this study as increases in variety and decreases in sizes of each cover type within a certain area. Corridors are defined as interconnected areas of the same cover type. Raw data for the landscape analysis are found in Appendix H (1937 grid-cell data), Appendix I (1993 grid-cell data) and Appendix J (grid-cell ownership).

Historic vegetation cover types

In 1937, the landscape consisted mainly of closed forest (35%), grassland (22%), and even-aged, closed forest acreage (18%) (Figure 22a). Private owners and the federal government possessed approximately equal amounts of closed forest (2335 acres and 3287 acres, respectively). Private land owners possessed most of the grasslands (3137 acres). Federal grasslands totaled only 370 acres; with 100 acres located in the RNA.

In 1937, the grassland consisted mainly of three large patches in the western portion of the analysis area (Figure 21). The patches were separated by major rivers but fairly contiguous. They did not have many patches of savannah tree or savannah shrub on the edges. They did, however, have some canyon forests at the interface between the grasslands and closed forests. The closed forests contained open areas with abundant patches of both grassland tree and open forest. The far eastern edge of the analysis area consisted of large areas of even-aged trees (Figure 21), indicating major disturbances in the area previous to 1937. Very little area in the closed forest was obviously clearcut or silviculturally treated.

In 1937, Sawmill Creek RNA consisted mostly of grassland and closed forest. Minor grassland tree and open-forest cover existed at the interface between the grassland and forest. In the northwestern area, a few acres of grassland shrub existed (Figure 21).

1993 vegetation cover types

By 1993, vegetative cover comprising the entire landscape changed significantly (Figure *). The main changes included less contiguous acreage of grassland than in 1937, more extensive agricultural fields, and more fragmentation of closed forests (Figure 21). By 1993 there is one large, contiguous patch

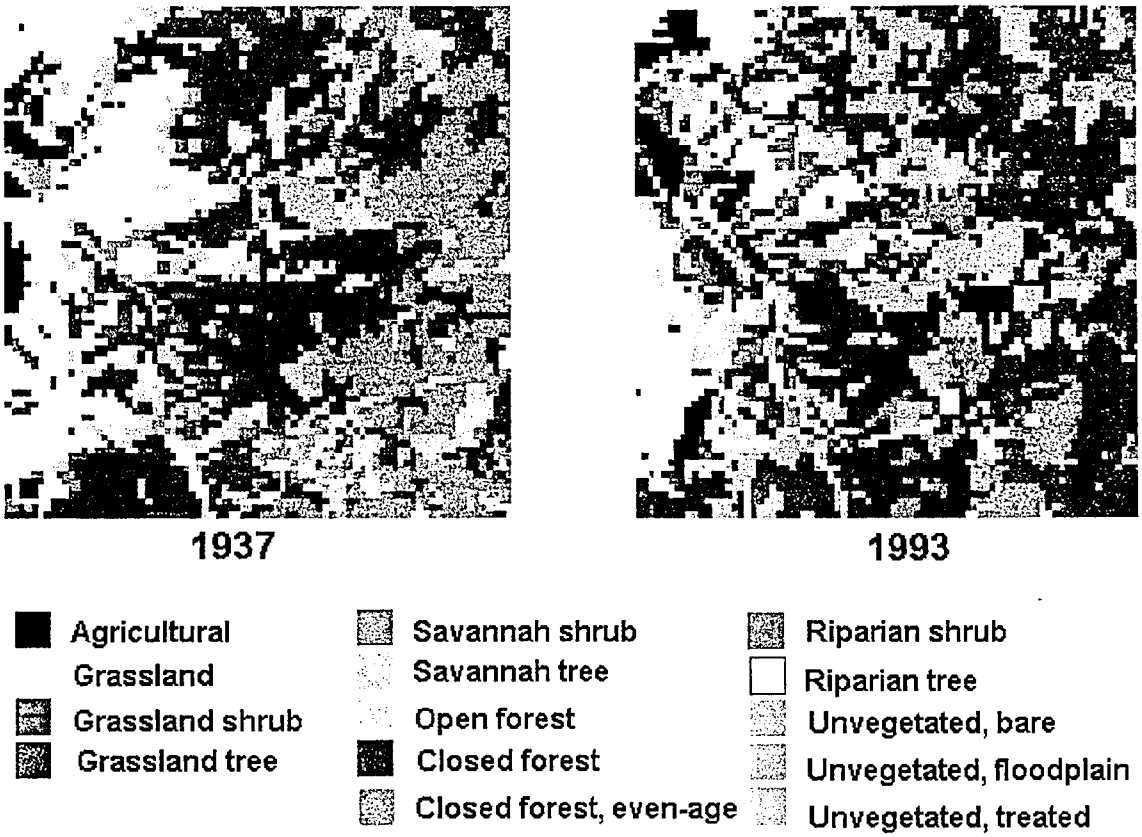


Figure 21: **Maps of vegetation cover types, 1937 and 1993**

of grassland left on the western edge of the landscape (Figure 21). The other grassland patches that existed in 1937 were covered with very small patches of grassland tree, savannah shrub, and open forest (Figure 21). Agricultural fields, both fallow and currently cultivated, also covered areas that previously were natural grasslands (Figure 21). Many acres of floodplain cover were also removed for agriculture. By 1993, agricultural land increased to 4% of the total landscape area (Figure 22). The closed forest also underwent tremendous changes during the 56-year interval. Even-aged, closed forests became closed forest with visible emergent trees (Figure 22). The effect of this growth was to form a more contiguous closed forest, especially on the eastern edge of the analysis area. However, the continuity of closed forest created by the maturation of these even-aged trees was offset by large patches of clearcut land (Figure 21).

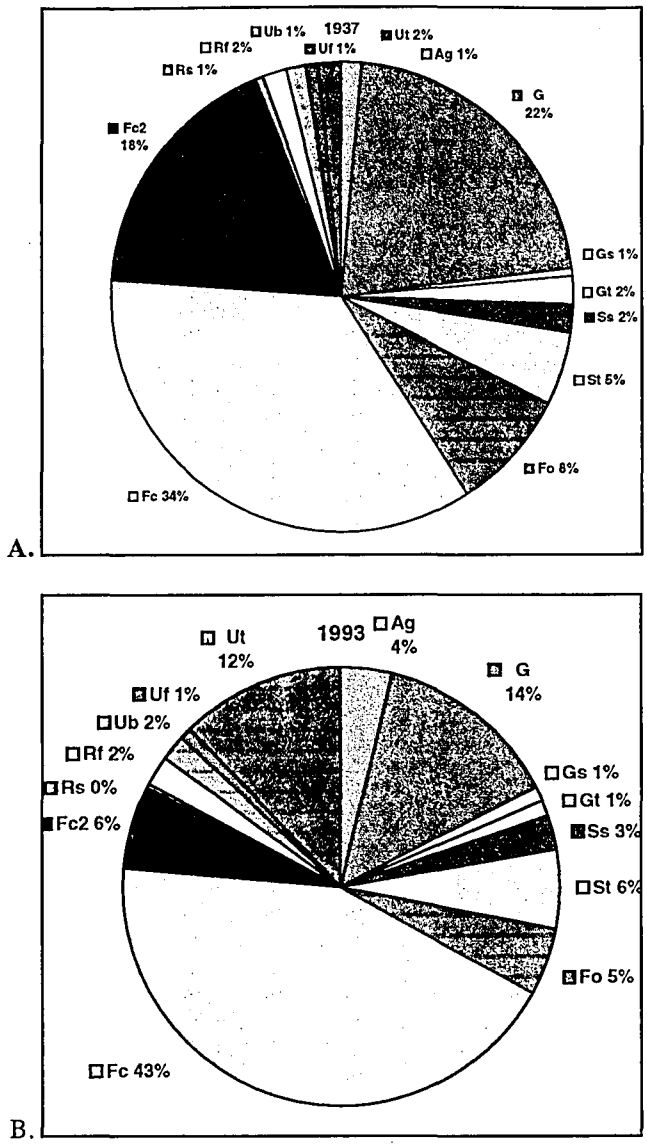


Figure 22: **Proportion of canopy cover types a) 1937 and b) 1993**

Silviculturally-treated land comprised 12% of the landscape by 1993 (Figure 22). It was a major cause of fragmentation in the closed forests (Figure 21).

Evidence supports the hypothesis that anthropogenic changes radically affected the landscape during the past 60 years. Anthropogenic change relates intimately to ownership. The percent change in each cover type by owner is shown in Figure *. Private land more than tripled in agricultural use from 1937 to 1993 (from 200 acres to over 600 acres, respectively, Table 4). Grain production became an important economic driver to change the landscape after settlement in the Sawmill Creek area. Private

agricultural land increased at the expense of river floodplains and 400 acres of privately-owned natural grasslands (Figure 23). As a result, habitat for natural grassland species diminished. Movement of grassland species also became increasingly limited with loss of grassland because habitat connectivity diminished (Figure 21).

Silvicultural treatment of varying intensity affected both private and federal lands (Figure 23). Logging was, and still is, a driving economic force in the Bitterroot Valley. The RNA had 35 acres that appeared logged (Table 4). The landscape had approximately 2000 (Figure 22). A decrease in closed canopy forest within the RNA itself is mainly attributed to high-grade logging in the westernmost

Table 4: **Acreage changes in vegetation cover types by ownership between 1937 and 1993**

Cover Type	1937 Private (acres)	1993 Private (acres)		1937 Federal (acres)	1993 Federal (acres)		1937 RNA (acres)	1993 RNA (acres)		1937 Total (acres)	1993 Total (acres)
Ag Agricultural	200	607.5		0	2.5		0	0		200	610
G Grassland	3137.5	1927.5		272.5	180		100	72.5		3510	2180
Gs Grassland shrub	27.5	110		52.5	45		5	12.5		85	167.5
Gt Grassland tree	217.5	112.5		87.5	35		7.5	37.5		312.5	185
Ss Savannah (shrub)	182.5	365		120	47.5		2.5	5		305	417.5
St Savannah (tree)	395	740		372.5	160		17.5	25		785	925
Fo Forest (open canopy)	367.5	462.5		957.5	330		25	25		1350	817.5
Fc Forest (closed canopy)	2335	2232.5		3167.5	4612.5		120	60		5622.5	6905
Fc2 Forest (closed, even)	7.5	10		2857.5	980		0	0		2865	990
Rs Riparian (shrub)	40	22.5		42.5	2.5		0	0		82.5	25
Rf Riparian (forest)	260	310		2.5	40		7.5	7.5		270	357.5
Ub Unvegetated talus/bare)	32.5	77.5		182.5	250		0	5		215	332.5
Uf Unvegetated floodplain	142.5	110		0	0		0	0		142.5	110
Ut Unvegetated treated?	135	392.5		120	1550		0	35		255	1977.5
Total Acres	7480	7480		8235	8235		285	285		16000	16000

drainage and clearcutting on the northeastern boundary before RNA establishment (Figure 24). Figure 24 shows how logging created more open canopy conditions in many portions of the RNA than in 1937. Cutting also eliminated some closed forest altogether from the eastern and western drainages (Figure 24). Surprisingly, the proportion of silviculturally treated land to total land area is similar in both the RNA and

non-RNA lands. The RNA had a 12% increase in silviculturally treated land between 1937 and 1993 (Figure 22). The non-RNA had an 11% increase in the same period.

Silvicultural treatment dramatically affected the land mosaic by 1993 (Figure 21). Federal land lost over 200 acres of savannah tree cover mainly because of selective cutting during the time period (Table 4). Blocks of clearcut forest created large, open areas within the closed forest that was insufficient cover for interior wildlife species. Clearcutting, therefore, reduced the habitat for these interior-forest species. Large, clearcut blocks also interfer with habitat connectivity and movement of interior species because they offered little cover to interior species and possessed altered vegetatation. Connectivity between previously connected closed forests was also substantially reduced by these clearcuts (Figure 21). In spite of the numerous, scattered clearcuts (Figure 21), however, federal land actually increased in

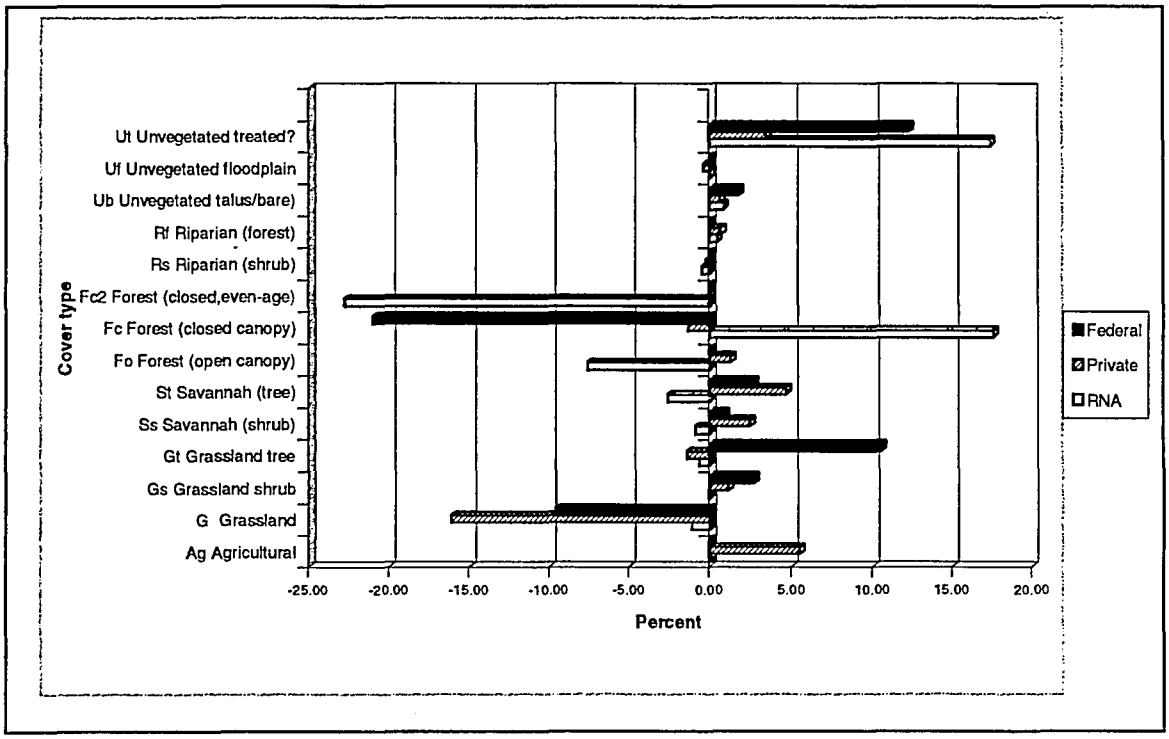


Figure 23: **Percent change in acreage by ownership from 1937 to 1993**

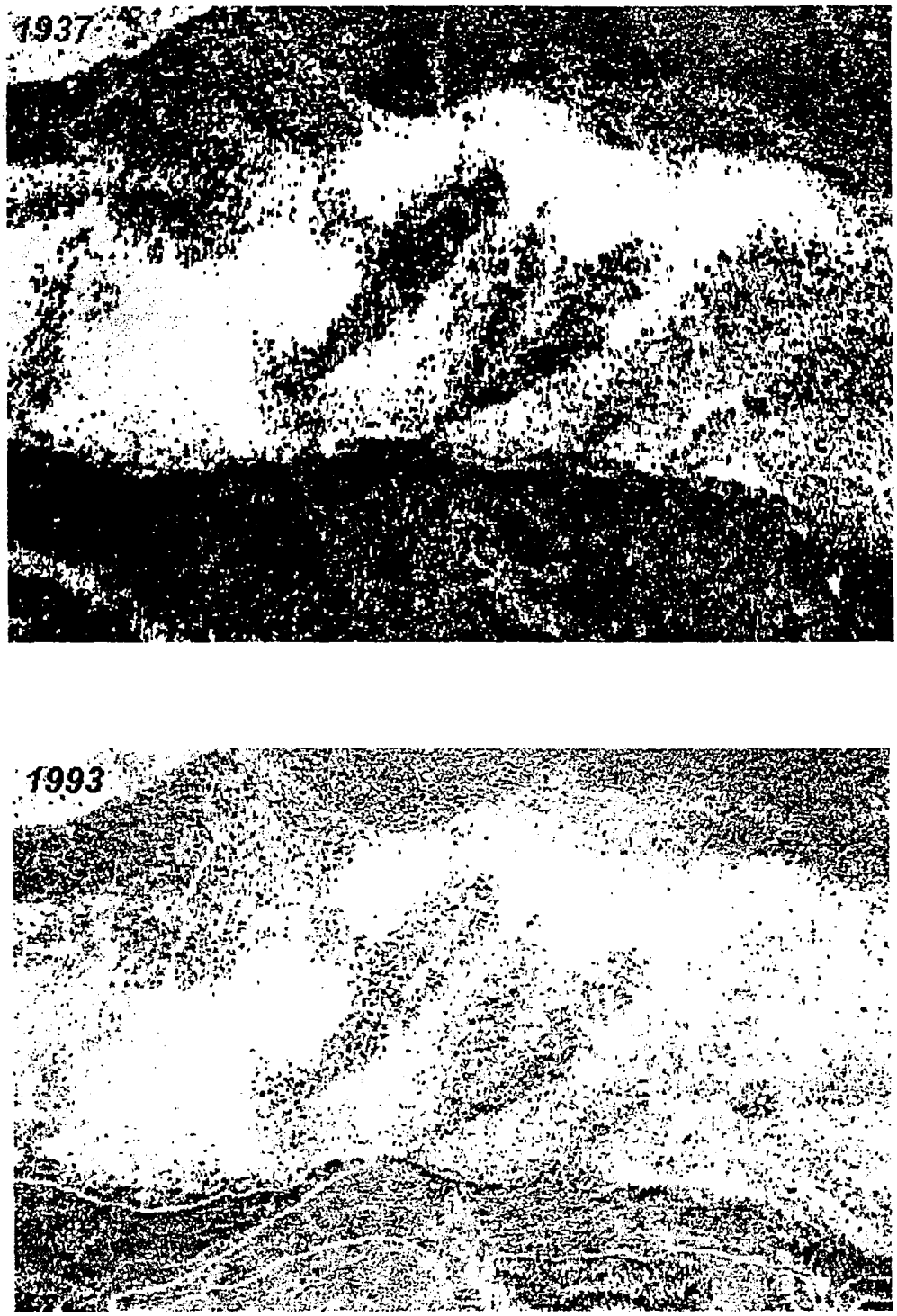


Figure 24: Comparison of 1937 and 1993 aerial photos for RNA area (top=1937; bottom=1993).

closed forest coverage in the past 60 years (Table 4). Much of this increase was attributed to the even-aged forests ("Fc2") that matured by 1993. By 1993, closed forest comprised over 4600 acres of the landscape on Bitterroot NF and Lolo NF land (Table 4), which is an increase of 17.5% from 1937 (Figure 23).

Evidence suggests that the relative proportion of each cover types changed on the landscape in 60 years due to natural succession that progressed unchecked by major disturbance events. Not only did the grasslands diminish because of farming, they also diminished because grasslands were invaded by trees and shrubs resulting in grassland tree, grassland shrub, and savannah cover (Figure 21). Within the RNA, grassland coverage decreased about 10% between 1937 and 1993 from 100 acres to 72 acres (Table 4). An accompanying increase occurred in grassland tree (from 3-13%) and savannah tree (from 6-9%) coverage (Figure 22). Figure 24 shows the aerial photos for the RNA. Between 1937 and 1993, most of the shrub and tree cover increase on RNA grasslands occurs on the northern and southwestern boundaries and between drainages (Figure 24). The photos also show the silvicultural changes that occurred in the surrounding landscape at the RNA boundaries and the thinning that occurred in the RNA. Grassland also diminished on federal land by 90 acres (Table 4). There were, however, no increases in either grassland tree/shrub or savannah tree/shrub to indicate a clear replacement for grassland. In fact, all grassland and savannah cover types declined slightly on the federal land (Table 4).

Open canopy forests on federal lands also declined substantially over the same time period (Figure 23). The landscape lost over 500 acres of open-canopy forest, all of which was on federal land. None was lost in the RNA. Accompanying the loss of acreage was a shift in the land mosaic. In 1937, open forest patches were located mostly within the closed forests or on the edge of closed, even-aged forests. By 1993, trees in these scattered patches grew or were invaded by other species and produced closed forest (Figure 21). In 1993, most of the open forest was located on the forest/grassland interface. The loss of grassland and savannah acreage to trees from nearby forests was quite evident by the change from grassland to savannah shrub, savannah tree, or open forest at this interface (Figure 21).

Cover type changes did not occur in the same proportions within RNA and non-RNA lands (Figure 25). In general, both of these land areas experienced a loss in grassland. The loss was

accompanied by a general increase in grassland tree/shrub and savannah tree/shrub cover (Figure 25). In the RNA, however, grassland tree cover increased over 10 times that of the non-RNA lands. In addition, grassland shrub and savannah tree covers increased by a small percentage more within the RNA than within the landscape (Figure 25). Savannah shrub did not increase any more on the RNA than on the non-RNA lands. Another significant difference between RNA and non-RNA lands was a 21% decrease in closed forest cover in the RNA verses an 8% increase in non-RNA lands (Figure 25). This difference, as explained above, was attributed to cutting in the RNA and the growth of small trees in closed, even-age forest covers.

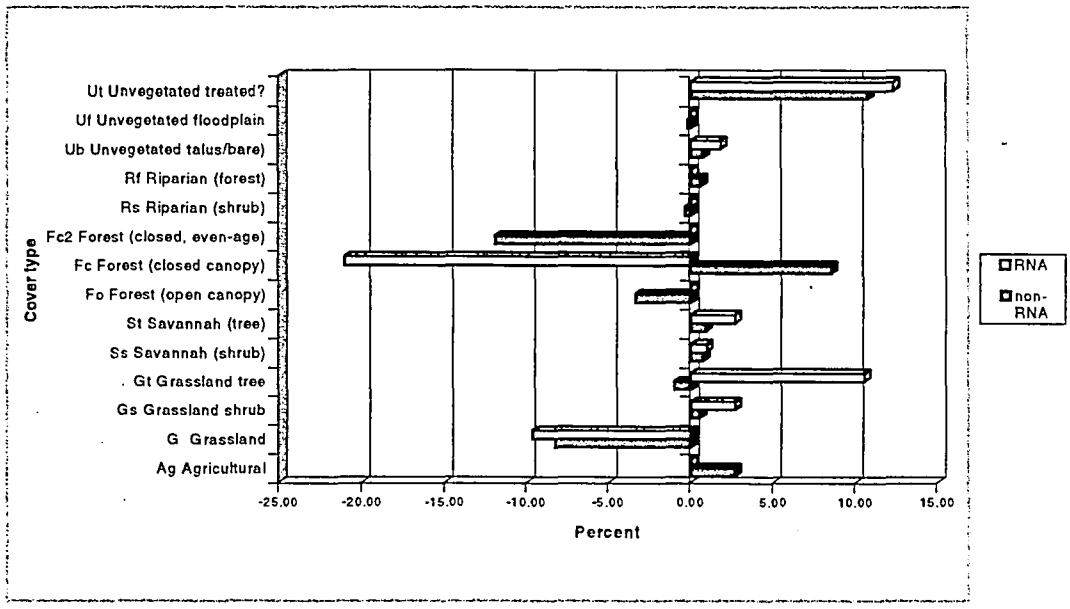


Figure 25: Percent change in cover type on RNA and non-RNA land between 1937 and 1993.

Paired student t-tests showed that the differences in proportions of cover types between the RNA and non-RNA land areas were significant in both 1937 and in 1993 (Table 5). Statistical results for the 1937 data were t=2.557 (df=13 and t_c=2.160, p<.05). Statistical results for the 1993 data were t=2.352 (df=13, p<.05). Statistical differences, therefore, became less from 1937 to 1993. Alternately, there was **no** significant difference between the RNA and the **other federal land** in either 1937 (t=2.044, df=13, p<.05) or 1993 (t=1.728, df=13, p<.05). This result was expected because the RNA was treated like any other federal land up until 1992.

Table 5: Paired T-test calculations for 1937 and 1993 RNA and non-RNA lands **

	Ag	G	Gs	Gt	Ss	St	Fo	Fc	Fc2	Rs	Rf	Ub	Uf	Ut	Sum	Mean	S2	Paired t-test	t-critical
1937 RNA	0.0	100.0	5.0	7.5	2.5	17.5	25.0	120.0	0.0	0.0	7.5	0.0	0.0	0.0	285.0	20.4	1079648.9	2.0	2.2
1937 Federal	0.0	272.5	52.5	87.5	120.0	372.5	957.5	3167.5	2857.5	42.5	2.5	182.5	0.0	120.0	8235.0	588.2			
Difference (d)	0.0	172.5	47.5	80.0	117.5	355.0	932.5	3047.5	2857.5	42.5	-5.0	182.5	0.0	120.0	7950.0	567.9			
d2	0.0	29756.3	2256.3	6400.0	13806.3	126025.0	869556.3	9287256.3	8165306.3	1806.3	25.0	33306.3	0.0	14400.0	18549900.0				
	Ag	G	Gs	Gt	Ss	St	Fo	Fc	Fc2	Rs	Rf	Ub	Uf	Ut	Sum	Mean			
1937 RNA	0.0	100.0	5.0	7.5	2.5	17.5	25.0	120.0	0.0	0.0	7.5	0.0	0.0	0.0	285.0	20.4	2600737.4	2.6	2.2
1937 Non-RNA	200.0	3410.0	80.0	305.0	302.5	767.5	1325.0	5502.5	2865.0	82.5	262.5	215.0	142.5	255.0	15715.0	1122.5			
Difference (d)	200.0	3310.0	75.0	297.5	300.0	750.0	1300.0	5382.5	2865.0	82.5	255.0	215.0	142.5	255.0	15430.0	1102.1			
d2	40000.0	10956100.0	5625.0	88506.3	90000.0	562500.0	1690000.0	28971306.3	8208225.0	6806.3	65025.0	46225.0	20306.3	65025.0	50815650.0				
	Ag	G	Gs	Gt	Ss	St	Fo	Fc	Fc2	Rs	Rf	Ub	Uf	Ut	Sum	Mean	S2	Paired t-test	
1993 RNA	0.0	72.5	12.5	37.5	5.0	25.0	25.0	60.0	0.0	0.0	7.5	5.0	0.0	35.0	285.0	20.4	1511783.5	1.7	2.2
1993 Federal	2.5	180.0	45.0	35.0	47.5	160.0	330.0	4612.5	980.0	2.5	40.0	250.0	0.0	1550.0	8235.0	588.2			
Difference (d)	2.5	107.5	32.5	-2.5	42.5	135.0	305.0	4552.5	980.0	2.5	32.5	245.0	0.0	1515.0	7950.0	567.9			
d2	6.3	11556.3	1056.3	6.3	1806.3	18225.0	93025.0	20725256.3	960400.0	6.3	1056.3	60025.0	0.0	2295225.0	24167650.0				
	Ag	G	Gs	Gt	Ss	St	Fo	Fc	Fc2	Rs	Rf	Ub	Uf	Ut	Sum	Mean			
1993 RNA	0.0	72.5	12.5	37.5	5.0	25.0	25.0	60.0	0.0	0.0	7.5	5.0	0.0	35.0	285.0	20.4	3073024.9	2.4	2.2
1993 Non-RNA	610.0	2107.5	155.0	147.5	412.5	900.0	792.5	6845.0	990.0	25.0	350.0	327.5	110.0	1942.5	15715.0	1122.5			
Difference (d)	610.0	2035.0	142.5	110.0	407.5	875.0	767.5	6785.0	990.0	25.0	342.5	322.5	110.0	1907.5	15430.0	1102.1			
d2	372100.0	4141225.0	20306.3	12100.0	166056.3	765625.0	589056.3	46036225.0	980100.0	625.0	117306.3	104006.3	12100.0	3638556.3	56955387.5				

** Level of significance = .05

Ag= Agriculture	Ss= Savannah shrub	Fo= Forest open	Rs= Riparian shrub	Ub= Unvegetated bare		
G= Grassland	St= Savannah tree	Fc= Forest closed	Rt= Riparian tree	Uf= Unvegetated floodplain		
Gs= Grassland Shrub		Fc2= Forest closed even aged		Ut= Unvegetated treated		
Gt= Grassland tree						

Discussion

A detailed look at the changes within the landscape shows that some of the changes relate to natural successional change and others relate to land use and ownership. The changes related to natural successional change include invasion of trees and shrubs onto grassland areas, invasion of trees onto riparian areas, and invasion and growth of small trees in open forests causing canopy closure. Changes relating to land ownership include increase in agriculture acres, increase in clearcut areas, and conversion of floodplain acres to agricultural fields. Both types of changes occur within all types of ownership examined in this study.

These changes in cover types also resulted in a change in land mosaic and in connectivity between like patch types. The land mosaic became much more finely divided. By 1993, small patches of savannah shrub, savannah tree, and grassland tree peppered the area that was once contiguous grassland. Major agricultural fields further reduced the natural grassland patch size, and separated the remaining grassland patches from each other. Areas along Burnt Fork Creek and its tributaries became much more finely divided by 1993 because of agriculture, clearcutting and invasion of trees and shrubs (Figure 21). Areas of once fairly contiguous closed forest for interiour wildlife species became separated by numberous small blocks of clearcut forest. Areas of bare rock and talus were much more visible on aerial photos by 1993 because of the extent of clearcutting.

Habitat connectivity for both grassland and interior species changed considerably during the 56 year period. In 1937, grassland species could move fairly freely between the rivers and grasslands. By 1993, however, river areas became increasingly disconnected because grasslands increased tree and shrub cover. Grassland species had much less continuous open space for movement corridors (Figure 21). Habitat connectivity for interior species, on the other hand, actually improved in some areas of the Bitterroot National Forest between 1937 and 1993. The most improvement area was in the southeast portion of the landscape area where open forests matured, filled in and became closed forest (Figure 21). The northeast corner of the landscape area also improved corridors for interior species because the closed forest cover became more continuous. However, the continuity of this closed-forest was partially

destroyed by logging. The area was logged in large, clearcut blocks and, therefore, retained fragmentation (Figure 21). Although the logging contributed to fragmentation, it also increased "edge". Continuity of cover types was most affected in the central landscape area surrounding Sawmill Creek. This area became very fragmented with similar cover types very small in size and very discontinuous. The logging, however, created abundant edge, similar to the northeast corner, for species that thrive in edge habitat. Deer, rodents, and some birds are among the edge-loving species. Some of these edge-loving species currently create problems in the RNA because they overgraze the natural grasslands. Corridors for edge species were abundant both within the RNA and in the landscape surrounding Sawmill Creek in 1993 (Figure 21). There is good connectivity between the RNA and non-RNA land for species that prefer the partial cover of edge habitats.

Sawmill Creek RNA is a unique place in the landscape. Even though the grasslands of Sawmill Creek RNA have diminished in size considerably since 1937, they are still the largest grasslands remaining on federal land in the 25 mi^2 study area (Figure 21). They were not unique in terms of the natural processes affecting them, however. All of the grasslands experienced successional changes that converted grassland to grassland tree, shrub or savannah. These changes occurred to various degrees on private, federal and RNA land. The trends in grassland loss will continue in the RNA and on the landscape in the absence of disturbance to curb their progression. Reversing this trend is critical to protect the growing space and floral diversity of the communities targeted for preservation in Sawmill Creek RNA.

Chapter 3: Recommendations for Restoration

Introduction

Restoration is defined in the Oxford English Dictionary as "the action of restoring to a former state or position." According to Saunders and others (1993), it is "totally unrealistic to believe that landscapes can be restored to their former state and incorporate all the original elements and functions because ecological understanding and practical expertise are not equal to the task." This philosophy applies equally to the landscape surrounding Sawmill Creek and to Sawmill Creek itself. The two time periods investigated for this study - 1937 and 1993 - were investigated only on the flat, stagnant surface of aerial photographs. We cannot return to 1937, or any other period in history, to have complete ecological understanding of the plant communities comprising Sawmill Creek or the processes that maintained them. We don't have plant records or research data to know what plant associations dominated Sawmill Creek in the past or how they interacted with each other. Hints of structural characteristics in 1937 can be derived from the aerial photographs, but not details on the exact makeup of the understory or how it functioned. Neither is there evidence that returning to 1937 vegetative composition is a better ecologic condition than the communities we have in 1993 or 1996.

In addition to knowledge, two other key limitations also affect restoration efforts. The influences of climate change and historical factors on the landscape were continuous and, in most cases, irreversible (ref**). Climate influenced migration, adaptability, and survival of plant and animal species. Historical factors influenced habitat size and location, fragmentation, wildlife movement, habitat connectivity, interspecific competition, introduction of exotic species, and many other factors that control the extent and composition of floral cover on the landscape. The landscape is a dynamic system that responds to these influences with species and cover type changes. Most of these influences can no longer be reversed in any restoration effort.

Pre-1935 is considered by Brown and others (1995) as "pre-settlement", which is a term commonly used in fire history studies to refer to the time before fire suppression became effective. Many stand-level studies have shown that the ponderosa pine/ Douglas-fir associations that comprise the drainages of Sawmill Creek were under frequent, non-lethal, under-burn fire regimes in pre-settlement

times (Brown and others, 1995; Arno, 1976; Arno, 1980). Similarly, the grassland at Sawmill Creek would have experienced these same, frequent, low-intensity fires. In 1937, which is at the interface between effective fire suppression and the natural fire regime, aerial photos show Sawmill Creek consisted of grassland, savannah and closed-canopy, ponderosa pine/Douglas-fir forest in proportions of approximately 10:2:15 respectively (Table 4). Arguments may be proposed to return to these proportions in the RNA as an initial attempt to restore Sawmill Creek to its "pre-settlement" condition. However, conditions have changed so much in 60 years that such a "restoration" to pre-settlement conditions would be expensive if it were even possible to achieve. At the landscape scale, too many mature forest areas have been cut, too much land has been lost to agriculture, and too many areas have undergone natural succession and weed invasions that changed the plant associations and interactions.

Central to the issue of "restoring" Sawmill Creek is the assumption that it is a damaged ecosystem that needs some repair. If "restore to a former state or condition" is not attainable, how should restoration be defined in practical terms? The ecological data collected for this study creates a baseline for present knowledge. According to Daly (1993), we can use the present ecological data and knowledge to attempt to create a "self-sustaining ecosystem that has structures and functions that are ***similar*** to those of the predisturbance system" and that meet the requirements of the ***purpose*** of this particular research natural area. Within this framework, several important predisturbance structures and functions need restoration. The natural process of fire needs to be restored to Sawmill Creek. Some grassland acreage needs to be restored and the target grasses revitalized to improve plant and seed production. RNA forests need open-canopy structure restored so that target vegetation needing open habitats can survive. Even restoring these three elements won't be easy. Because Sawmill Creek RNA is such a small area within a large, dynamic landscape, it will never be a "self-sustaining ecosystem." Current RNA policy requires the grassland and conifer/grassland communities be preserved for future generations, yet ecological forces from both within the RNA and outside the RNA have worked to dwindle grassland acreage for the past 60 years. Sawmill Creek must remain a very small island in a sea of future successional and anthropogenic change. It will take active, aggressive management to counter these powerful natural ecological processes..

Situation Statement

Ecologic conditions affecting restoration in RNA

Site analysis of Sawmill Creek RNA for this study shows it to be a diverse ecologic setting consisting of five distinct communities (see Chapter 1). Each of these communities varies in degree of biological richness and biodiversity (Appendix D) and is controlled by unique ecologic factors that should be protected and/or addressed in any restoration plan. Each community also differs in predominant disturbance regime and forces acting to degrade it.

The ***grassland*** averages over 36 herb and grass species per 1/10 hectare. The main degrading forces in this community are (a) invasion and expansion of weedy species; (b) invasion of shrubs and trees; and (c) overgrazing of bunchgrass plants. Appendix D shows that weedy species comprise up to 14% of grassland study plots, including several introduced, noxious weeds. Landscape analysis shows that grassland conversion to savannah or shrub savannah is prominent within the RNA and within the landscape study area (Table 4 and fig. 16). Within the RNA, over 25 acres of grassland changed dominant cover to mixed-tree savannah or shrub savannah since 1937. Historically, grazing by cattle was not extensive in the RNA (Habeck, 1992). Currently, overgrazing by ungulates and rodents, is the main contemporary disturbance regime in this community (see Chapter 1).

The ***shrub savannah*** is second only to the riparian area in diversity and richness (Appendix D). The main degrading force in this community is weed invasion by spotted knapweed and cheatgrass, probably introduced during historic road-building, logging and minor grazing in the RNA. Landscape analysis shows that grassland-shrub and savannah shrub were a historical part of the RNA in 1937. By 1993, this shrub-dominated cover expanded over 10 acres within the RNA, mainly at the expense of grassland acreage (Figure 22). Like the grassland, the grasses and shrubs in this community are browsed and have minor litter accumulation.

The ***mixed-tree and shrub savannahs*** are threatened by both weed and tree invasion. Figure 11 shows that the savannah areas established a substantial number of Douglas-fir trees in recent years (mean=33 trees/hectare in 5-9 cm dbh class). Ponderosa pine increased in density in the smallest size

class (i.e. 5-9 cm dbh) to 14 trees/hectare (Figure 11). The RNA mixed-savannah accumulated a substantial quantity of coarse woody debris (Figure 18) including partially-burned stumps from past logging operations and insect-infested snags. Combined litter and duff depths in this community varies considerably from 0 to 16.5 cm thick. Landscape analysis shows that many areas that were classified as savannah shrub and savannah tree in 1937 convert to open or closed forest by 1993 (Figure 21). The main disturbance agents observed in mixed-savannah plots were grazing and selective logging.

Forest communities were the least diverse communities in the RNA (Appendix D). They contained an average of only 33 species, over half of which belong to the Compositae (Asteraceae), Graminaceae (Poacaeae), and Roseaceae families. 99% of the species were perennial. Introduced or weedy species were rare and no noxious weeds were found (Appendix D). Structurally, the forests consisted mainly of three cohorts. The oldest cohort contained large, dominant ponderosa pine or codominant ponderosa pine and Douglas-fir. The middle cohort consisted mainly of Douglas-fir. The youngest cohort consisted mainly of Douglas-fir with rocky mountain juniper or mountain maple (Appendix B). The ponderosa pines, in general, had very little regeneration, low density in the smaller size classes (Figure 11) and poor vigor (Figure 14). Their cones are infested with cone worms (Figure 16) and many seedlings exhibited clipped branches and missing apical buds indicative of browsing (Figure 17). Douglas-fir, in general, had high density (Figure 11), poor seedling survival (Figure 10), and indications of disease infestation (mistletoe?). Woody debris was abundant. Its decay conditions varied between drainages in the RNA with more decayed coarse woody debris in the western and central drainages. Litter and duff accumulation was not extensive and ranged from 1 cm to 3 cm. Grasses and sedges in the forest had more dead leaves and stems than the grassland plants for fire fuel. Landscape analysis showed that open forest acreage in the RNA remained constant between 1937 and 1993 (Table 4) while open forest declined on non-RNA land. Closed-canopy forest in the RNA decreased over 20%, mainly due to logging (Figure 21, Table 4). The disturbance agents operating in the forest observed for this study, included logging, fire, insect and disease infestation, windfall and grazing.

Riparian forest was the most diverse community in the RNA. Study plots contained over 40 species each. Many of these species were found only near Sawmill Creek (i.e. they have low constancy).

Most were perennial (Appendix D). Weedy species comprised up to 10% of the total species (except in plot 25 which is not at the river), and noxious weeds are present. The riparian plots' are located in a physical environment that promotes diversity and richness. The creek is located at the base of steep valley walls. The creek bottom is well shaded by mature overstory trees and shrubs. Shrubs and small trees, such as service berry, alder and chokecherry, are tall and reach to the conifer overstory. Lush, shade- and moisture-loving plants thrive near the river. Within a few meters of the river, steep, dry slopes or talus dominate the hillsides. Therefore, the diversity within a single riparian plot ranges from plants requiring abundant moisture to plants of dry, coniferous forests or "desert" talus. Several old-growth trees (approx. 200 years old) of poor vigor also survive in this community (Figure 14, Appendix F). The main forces acting to degrade this community include: (a) accumulation of coarse woody debris on the forest floor; (b) increased density of shrubs and coarse woody debris in understory; and (c) soil compaction and trampling of the unique vegetation by humans and animals. Coarse woody debris is very abundant. Much of the deadfall is not located right at the river where moisture would hasten decay but on the drier slopes where it decays slowly. Not only does this area accumulate its own debris, but cut and windblown trees and debris roll down the steep slopes and accumulate at the base of talus slopes near the creek. Although the woody debris is abundant in decay classes which are important to fire risk, it is questionable how continuous a fire these fuels would create because of the talus. Near the creek itself, small windthrown trees and dense tangles of dead current, ninebark and mountain maple branches increase the fuel load and make access difficult. Footpaths and deer paths are abundant in this area because negotiating the talus, dense shrubs and deadfall is difficult for both people and animals. The difficult access creates abundant routes through the dense, thorny shrubs, which creates trampling of the unique plants over a wide area. The main past and present disturbance agents include logging, windthrow, trampling, browsing and insect and disease infestations.

Interacting factors of evapotranspiration, aspect and amount of overstory available for shade control the growth and death of vegetation in the RNA. Detrended correspondence analysis discussed in Chapter 1 (Figure 6) revealed that the amount of moisture available to the plants is probably the most important control on the floral composition of the five communities. Timing and intensity of restoration

techniques will have to be guided by this controlling factor. Especially critical will be timing the reintroduction of fire to the very dry grassland systems. Restoration in the grasslands should be conducted when moisture is high so that there is minimal damage to the root systems of the dryland plants and there is less danger of wildfire. Normally, spring burning will be the least detrimental to bunchgrass plants because the higher moisture levels keeps fire from becoming too hot in the sensitive root culms. However, spring burning can also be more detrimental to cool-weather grasses, such as rough and Idaho fescue, because they initiate growth very early. Burning fescue grasses while they are actively growing results in less resiliency for recovery and greater mortality in the community (Redmann and others, 1993). Therefore, timing the reintroduction of fire will be a delicate balancing act based mainly on the moisture available in the communities, the growth form of the plants, the fuel load adjacent to growing tissues, and the phenological growth stage of the plants (Rasmussen, 1994) . On the one hand, burning needs to be conducted when fuels are continuous and dry enough to ignite and carry a fire. On the other hand, it needs to be conducted when spring grasses are essentially dormant to prevent severe mortality to individual plants and loss of important target communities.

Landscape analysis of the RNA and surrounding area shows that change is inevitable. In just 60 years, the area has experienced an increase in agriculture, a loss of many acres of grassland, and increase in treatment areas that completely change the functions of plant communities and the activities of wildlife that inhabit them (Figure 21, 19). Changes from outside the RNA have dramatic effects on vegetation growth and usage within the RNA. For example, clearcut logging outside the RNA affected animal movement through the RNA. Animal use of the RNA for browse and cover has led to overgrazing of both the grasses and the trees. Grassland conversion to agricultural acreage outside the RNA also increased RNA use by species that require natural grassland habitat. Changes within the RNA have much less effect on the landscape because of its small geographic size. At both scales, fragmentation has increased dramatically since 1937 (Figure 21). The landscape shows a change from three large grasslands to one grassland and a mosaic of finely-divided cover types in the other grasslands (Chapter 2; Figure 21). The RNA shows conversion of grassland to small patches of grassland tree and savannah shrub cover types. Habitat connectivity for both grassland species and interior species are much more limited than in the past

(Chapter 2;Figure 21). Wildlife and avian usage of these forests and grasslands obviously must change as anthropogenic cutting and natural succession create more and more edge in the national forests and less grassland for wildlife habitat.

Policy governing restoration in RNA

The objective of the RNA as set forth in the establishment record is "to maintain and preserve the features of the RNA in as near an undisturbed (by humans) condition as possible" (Habeck and others, 1992). The habitat types (Pfister, 1977; Mueggler and Stewart, 1980) targeted for preservation consist of a combination of relatively high-quality conifer/grassland and grassland species (see Chapter 1). Sawmill Creek is a typical RNA in that its existence centers on preserving these specific communities while at the same time providing a site for long-term environmental quality monitoring (Moseley, 1990). In such sites, "natural processes will be allowed to operate ... within the constraints outlined in FSM 4063.3 (RNA Protection and Management) and FSM 4063.34 (Vegetation Management)." (Habeck and others, 1992).

Under FSM 4063.05, a research natural area is "a physical or biological unit in which current natural conditions are maintained insofar as possible by ***allowing natural physical and biological processes to prevail*** (emphasis added) without human intervention." The "prime consideration in managing research natural areas is maintenance of unmodified conditions and ***natural processes***" (FS Manual 4063.3, emphasis added). Emphasis of both FSM sections is on **naturalness, preserving diversity, and protecting target vegetation in perpetuity.** Several management practices are frowned upon in RNAs including: logging, grazing by domestic livestock, development for recreational use, insect and disease control, mining, and road building. However, many of these management practices are allowed in special circumstances to protect the vegetation or where the management practice "provides a closer approximation of the naturally occurring vegetation and the natural processes governing the vegetation than would be possible without management" (FSM 4063.34 - Vegetation Management). FSM 4063.34 specifies that control of noxious weeds, grazing, control of animal populations or prescribed burning are acceptable management practices "to preserve the vegetation for which the research natural area was created." Control of exotics or weeds, or pest management, is desired (sec.

4063.32) but must be "as specific as possible against target organisms and induce minimal impact to other components of the ecosystem" (sec. 4063.3). One of the most controversial issues facing many RNAs is the role of fire to maintaining natural vegetation. Sections FSM 4063.41, 4063.34, and 4063.32 conflict on the role of fire in the RNA. **Section 4063.41** (Establishment Record Content: Management prescription-vegetation management) states that prescribed burning can be used in and near the research natural area to maintain ecologic conditions. However, "only part of the RNA can be allotted to burning; part must be reserved for permanent protection" . **Section 4063.34** (Vegetation Management) states that "the Forest Supervisor may authorize management practices (including prescribed fire) to preserve the vegetation for which the research natural area was created." It also says "use fire to preserve a vegetation type only when absolutely necessary." **Section 4063.32** (Resource Protection Guidelines) requires fire suppression by "extinguishing as quickly as possible fires that endanger research natural areas".

The concepts of preserving exact habitat types with specific species, allowing natural processes to operate, and suppressing the natural process of fire, which are central to the RNA policy, are contradictory. The results of this study show that rapid change is inevitable on both the large and small scale if "natural" processes are left to operate (Figures 18 and 19). The results also show that anthropogenic activities in the landscape surrounding the RNA severely alter the ecologic environment for both economic and social reasons (Figure 25).

Change in time and space is documented in this study by fluctuations in canopy density. Some of these changes are caused by man; others are caused by natural succession. Changes in canopy density necessarily affect species targeted for preservation if their habitat expands or diminishes. Although this study can only document changes in acreage allotted to each cover, not changes in specific species over time, species change obviously occurs when cover types change on the landscape. In the specific case of the grassland species targeted for preservation in Sawmill Creek, their habitat has diminished by approximately 25% since 1937. Changes in species composition and dominance obviously occur when open grassland habitat changes to sage- or tree-dominated grassland or savannah. Therefore, the question to be addressed by these contradicting policies is, how far will natural change, or succession, be allowed to occur and at what price to the habitat of species targeted for preservation?

Allowing only natural processes to operate in the RNA but suppressing the natural process of fire is a basic contradiction in policy. Articles by politicians, scientists, and wilderness specialists argue that the two concepts of "naturalness" and "fire suppression" are not compatible (Jolly, 1995; Bradley, 1995; Pyne, 1995; Morton, 1995). Ironically, many of these studies are for other natural areas, such as wilderness areas or parks, which concede that fire is a natural process and must be allowed to burn. The question of whether fire is regarded as a natural process or simply a physical disturbance (i.e. "a change in the "normal" processes that control a particular ecosystem") is addressed by White (1987). If pre-settlement conditions required fire for maintenance of the specific conifer and grassland ecosystems targeted in this RNA, is that a deviation from normal or a process that controls? Whatever the individual answer, the policy of allowing the natural process of fire to operate in some "natural" areas and not in others, is a policy problem to big to deal with in this study.

Whether fire starts naturally from lightning or from human ignitions, it creates a complex mosaic of growing conditions on the landscape. Mosaics are created because of topographic variation, variation in vegetative cover, previous-burn history, moisture differences in plants or soil, variations in dominant driving forces (such as wind), variation in vegetative condition, amount of ground fuel or ladder fuels, and many other factors. Mosaics created by burn patterns result in variety of habitats that promote biodiversity in plant species and variety in animal use that is critical to long--term resiliency and survival of species in the RNA. Biodiversity promotes sustainability and resiliency in the landscape (Tilman and others, 1996). Therefore, whether fire is a natural process or simply a physical disturbance, it is an important process that must be returned to the RNA.

Current Forest Service RNA policy, except for fire suppression, did not create the specific ecologic and structural problems now observed in Sawmill Creek. The RNA was established only four years ago. If policy continues to make "maintaining unmodified conditions" and suppressing the natural process of fire the prime considerations in RNAs, it will be the main degrading force to long-term survival of the target communities of this particular RNA. It is shown in many studies that both the conifer/grassland community and the grassland community require burning to perpetuate themselves (Arno,1976; Wright and Bailey, 1982; Daubenmire, 1968). If Sawmill Creek is judged a "damaged"

ecological system without the natural process of fire, then active management will be essential to restore the structure and function of these communities to conditions more in line with pre-settlement or "natural" conditions.

Economic factors affecting restoration in RNA

Creation of the RNA for preservation of grassland and conifer/grassland habitats and protection of old-growth trees has intrinsic value, not extrinsic value. Certain costs, however, will be incurred to keep the area a quality grassland to showcase target species for future generations. These costs include weed control, fire management, road maintenance, and scientific monitoring. However, these costs will not be directly offset by income generated from the RNA. Economic forces working to degrade the RNA include a limited budget for supplies and man-power to aggressively control of weeds and tree and shrub invasion over the entire 270 acres. Restoration alternatives that require high-frequency, expensive treatments are impractical on a limited budget because many RNAs in the country are facing the same problems as Sawmill Creek (Evenden and Geeene, 1996). Since 1937, economic forces working at the landscape scale to degrade natural vegetation and wildlife habitat, which affect the RNA, include removal of large blocks of forest for timber (i.e. clearcuts) and expansion of agricultural acreage for grain production (Figure 21). Economic pressures to cut forest and convert grasslands on the landscape will place ecologic pressures directly on the RNA as animals increase use of RNA for browse, cover and corridors.

Sociologic factors affecting restoration in RNA

The benefits of this natural area to present and future individuals are spiritual, cultural, educational, historical, and scientific (Stankey and McCool, 1995). Aesthetic and emotional satisfaction is gained knowing the area will be available for present and future generations to enjoy as a small piece of "wilderness" in its natural state. The area has immunity from developers, ranchers, farmers, or contractors when populations grow in the Bitterroot valley. It will always remain a small "vestige of the natural world from which we evolved and with which we continue to feel a connection" (Stankey and

McCool, 1995). Historical value comes from preserving important vegetative communities that have survived in western Montana for centuries. Future generations can view and appreciate these communities just as the first settlers to western Montana did. Educational and scientific value spring from the opportunity to learn more about how these communities function and interact with each other in a natural environment over time. Other values may come from new drug discoveries, scientific insights, spiritual enlightenment, artistic or emotional inspiration, or genetic pools for species preservation or research. The area provides an opportunity to learn how the species in these communities evolve and adapt in this particular physical environment, in this particular climatic regime, under these particular disturbance processes.

The small size of the RNA and its proximity to private land places social constraints on any restoration alternatives. Allowing natural processes to operate in the RNA that endanger private land at RNA boundaries is not socially acceptable. Endangerment can range from actual destruction of crops, acreage or buildings, to degradation of air quality and soil condition in the vicinity of private land. Husari (1995) discusses the limitations of allowing natural fire in small natural areas near private land. The proximity of developed private land to RNA boundaries also means that RNA ecology is affected by private land management. The spread of weed species that are not controlled on private land creates particular risk to RNA "naturalness."

Social definition of what is "natural" will also underlie management alternatives in this RNA, as well as other natural areas in the country (Neckles, 1995). According to Neckels, public perception of "naturalness" usually does not include charred acres of grassland, forests or riparian areas. Likewise, allowing natural process, such as fire, to operate in the RNA can destroy valuable scientific studies, which is not socially acceptable to the scientists conducting the research. The same scientific studies on the RNA, however, also degrade RNA aesthetics and "naturalness." Plot markers from different studies vary in shape, size and color. In 1996, they were so abundant on some portions of the grasslands in that the ground resembled a pincushion. In fact, in plot locations where weed studies and this study overlapped, a minimum of five rebar markers and two large, visible PCV markers marked boundaries or plot centers within 1/10 hectare.

Restoration Goals

Restoration goals for Sawmill Creek RNA combine important aspects of the Ecosystem Management paradigm, including ecologic viability, economic feasibility, and social desirability. Because of the small RNA budget, policy directives associated with the RNA, and the small area involved with this natural reserve, accomplishing the combination of these goals will be extremely challenging. However, all four are equally important to the RNA objective to maintain five distinct habitat types in perpetuity.

*1). **ECOLOGIC GOAL**: Maintain quality, integrity, and stability of grassland and conifer/bunchgrass ecosystems and reverse processes leading to their degradation. Minimum goal would be to maintain viable populations of all native plant and animal species known to belong in the RNA.*

*2) **SOCIOLOGIC GOAL:** Eliminate conditions that may result in destruction of the RNA and its communities, such as fuel buildups for catastrophic fire. Use restoration techniques that create the fewest social problems (i.e. minimal air pollution, contamination of water supplies, crop destruction).*

*3) **ECONOMIC GOAL**: Make restoration as "self-sustaining" as possible so long-term maintenance of RNA communities is as practical as possible.*

*4) **POLITICAL GOAL**: Gather scientific evidence to help assess federal" non-management" and "fire-suppression" policies in natural areas by monitoring permanent study plots for changes in quality or diversity on regular basis. Show need to mimic natural process of fire using "active management" to preserve acreage and quality.*

Restoration Objectives

Short-term (1-5 years):

1) Restore the natural process of fire to the RNA.

2) Restore habitat for bunchgrass growth by reducing interspecific competition between weedy species and native grass and herb species.

3) Restore structure and composition of the riparian and closed-canopy forests to conditions more compatible with pre-settlement conditions to create conditions condusive for target bunchgrasses and conifers, which need open-canopy habitat.

4) Increase yield from root stocks of bunchgrass species targeted for preservation.

Long-term (5 years +):

5) Maintain quality (richness, diversity, low weed densities) of community types and overall RNA diversity. Grassland quantity and structure should not fall below those present at time of RNA establishment (1992). May want to target grassland and forest composition to compositions with similar dominant species and structure as those that existed in historic grasslands and ponderosa pine forests.

6) Increase regeneration of ponderosa pine in RNA so the forests can persist in the RNA to perpetuity.

7) Maintain "natural" look (aesthetics) and quality of "wilderness experience" or "natural experience" of RNA (i.e. no large areas of torched tree crowns, no clear-cut areas, few downed trees left on the forest floor to impede movement or plant growth, no additional vehicle track marks on grassland or in forest from restoration processes, controls on plot marker size and abundance)

Alternatives for Restoration

Table 6 lists several alternatives to meet each objective for the RNA and the advantages and disadvantages of each. Some of the alternatives are not feasible within the current economic and political requirements of the RNA. For example, using biological control as the sole source of weed elimination in the RNA is too expensive and too slow to meet current objectives. Therefore, it would not be a preferred alternative in the RNA at this time. It may, however, be a viable future option in the RNA when costs come down or policies change. The preferred alternatives for restoration in this study are highlighted in bold in Table 6. They are discussed in the following section.

Table 6a: Alternatives for restoration in grassland community

Objective	Alternatives	Advantages	Disadvantages
1. Eliminate weedy species	**Spray select areas**	Rapid results	Application must be repeated every 3 years Expensive Unknown long-term effects on biodiversity Unknown long-term effects on wildlife/insects Residual in soil/ effect on soil microbes Possible bioresistance by weeds in long-term Affect water quality- runoff from steep slopes will have herbicides in water Treatment not "natural"
	Aerial spray entire RNA	Rapid results	Same as above. Greater water-quality risk, greater expense, greater risk to wildlife and long-term biodiversity Social problems with adjacent private land and livestock
	Biological control	Natural	May take too long to get results Prohibitively expensive at this time Will take many types to control the variety of weeds and noxious plants in RNA Unknown effects on biodiversity if insects target other hosts
	Hand pull	Rapid results Least disruptive	Expensive unless done with volunteer labor Area too large to make this practical Feasible only to get rid of noxious , not entire range of weedy species
	No action	None	Interspecific competition with bunchgrass, long-term loss of biodiversity Loss of RNA integrity
2. Increase acreage for bunchgrass growth	Cut and remove encroaching juniper	Prevent conversion of grassland to savannah	Expensive, labor intensive (Isolated juniper pose no immediate threat to grasses. They compete for nutrients and water at different depths. Grasses grow well under them. May need action in long-term plan.)
	Cut and remove encroaching sagebrush	Prevent grassland conversion Increase nitrogen for bunchgrasses Reduce interspecific competition w/grass	Expensive, labor intensive Sagebrush seed residual in soil Nitrogen increase short-term; inorganic nitrogen leached more easily
	Burn to remove encroaching sagebrush	Reduce interspecific competition Increase nitrogen for bunchgrasses Cost & labor less than cutting	Burning needs to be hot to remove sagebrush, may destroy biodiversity with more intense fire Do not eliminate seed bank for sagebrush with fire May increase leaching of inorganic nitrogen
	No action		Continued loss of grassland acreage for target vegetation in RNA from succession

3. Improve vigor and regeneration of bunchgrasses	**Burn grassland**	Reduce interspecific competition Revitalize grasses Treatment interval long - 5 to 10 years Natural	Adverse effects on grasses if intensity of fire not properly controlled Short-term adverse effect on aesthetics of RNA Labor intensive/ expensive in short-term
	Fertilize grassland	Increase nutrients known to limit plant growth and vigor	Not natural, expensive, effects on water quality from runoff unknown May increase production of herbs at expense of bunchgrasses Questionable improvement on regeneration of bunchgrasses
	Seed grassland	Increased regen potential on bare soil Easy Cheap	No effect on vigor of existing plant Seed should be taken from surrounding area to ensure proper genetic composition and survivability
	Manage wildlife populations in surrounding areas (Late-season hunts?)	Increase grass production and regen in over-browsed areas of RNA	
	No action		Loss of biodiversity if grasses continue to regenerate poorly from plant deterioration and browsing
4. Retain plant, animal, insect biodiversity in long-term	Burn entire grassland area	Easy to determine reburn interval Less labor intensive than option below	Serious safety concerns and aesthetic effects Social risks to neighboring property; air quality concerns, runoff concerns Risky if fire not proper intensity - may lose more flora than desired Loss of habitat/niche for animals all at once; serious effects on native populations
	Burn portions of grassland to create mosaic	Creates mosaic of different aged grasses Animals/insects retain some habitat Get all advantages of burning, plus create biodiversity with mosaic of grasslands in different growth stages Conservative approach - still have local seed bank if burning goes awry	More difficult to implement return intervals for burning Labor intensive/ economic costs incurred every year, not once every 5-10 years
	No action		Loss of acreage will result in loss of biodiversity when habitats change with time. (Need to manipulate habitats to create diversity in time and space.)
5. Retain aesthetics of natural area in long-term	**Eliminate highly visual plot markers**	Improves aesthetics Less disruptive to wildlife	Scientists have more difficulty locating plots for future monitoring Will take "policing" from Forest Service personnel (minimal labor)
	No action	Research scientists can easily find plot locations	Continued degradation of "natural" aesthetics as more scientists do research in RNA

Table 6b: Alternatives for restoration in shrub-savannah community

Objective	Alternatives	Advantages	Disadvantages
1. Eliminate weedy species	**Spray select areas**	Rapid results	Application must be repeated every 3 years Expensive chemicals Unknown long-term effects on biodiversity Unknown long-term effects on wildlife/insects Unknown long-term effects on soil (residuals) and on soil microbes Possible bioresistance by weeds over time Affect water quality- runoff from steep slopes will have herbicides in water Treatment not "natural"
	Aerial spray entire RNA	Rapid results	Same as above. Greater water-quality risk, greater expense, greater risk to wildlife and long-term biodiversity Social problems with adjacent private land and livestock
	Biological control	Natural	May take too long to get results Prohibitively expensive at this time Will take many types to control the variety of weeds and noxious plants in RNA Unknown effects on biodiversity if insects target other hosts
	Hand pull	Rapid results Least disruptive Targets specific species	Expensive unless done with volunteer labor Area too large to make this practical Feasible only to get rid of noxious , not entire range of weedy species
	No action	None	Interspecific competition with bunchgrass, long-term loss of biodiversity
2. Limit aerial spread of community	Cut shrubs at edge of community	No need to control hot fire Labor minimal	Sagebrush seed residual in soil. Nitrogen increase short-term; inorganic nitrogen leached more easily Not natural process Effects may be short-term; many of the shrubs come back more vigorously after after pruning (i.e. sagebrush, rabbitbrush, wood's rose)
	Hand-pick sage seed to remove regen potential	Reduce regeneration and spread	Labor intensive on several year basis Won't affect seeds in soil bank
	Burn portion of sagebrush community	Reduce interspecific competition Increase nitrogen for bunchgrasses Cost & labor less than cutting Natural process	Burning needs to be hot to remove sagebrush, may destroy biodiversity with more intense fire Does not eliminate seed bank for sagebrush with fire May increase leaching of inorganic nitrogen May need to increase fuel load artificially to get fire hot enough and not destroy grasses Effects may be short-term; many of the shrubs come back more vigorously after cool fire (ie. sagebrush, rabbitbrush, wood's rose) Labor intensive to monitor spread and heat of fire, long cycles between treatments
	No action		Continued loss of grassland acreage for target vegetation in RNA from succession

3. Retain long-term biodiversity	**Periodically cut/burn to create openings in sage cover**	Creates spatial mosaic Animals/insects have variety habitat Creates temporal mosaic Conserves species for seed and renewal of flora Control interspecific competition of sagebrush with herbs/grasses	Needs planning to determine best return intervals for temporal mosaic Labor intensive/ economic costs incurred more often than one-time treatment May need research to determine best spatial spacing for shrub/grass combination to retain present biodiversity over long-term
	No action		Long-term expansion of savannah at expense of grassland

Table 6c: Alternatives for restoration in mixed-tree savannah community

Objective	Alternatives	Advantages	Disadvantages
1. Restore composition to p pine dominant	Select cut Douglas fir all ages in randomly selected areas	Mimics fire removal - non age specific	Age structure now skewed to young Doug fir; large size classes already dominated by ppine No guarantee to meet objective Could jeopardize old-growth Douglas fir; random removal of any large-diameter trees could eliminate an age-class Threatening one of target vegetation types - (i.e. Doug fir/ bunchgrass) Removal of large trees problematic (i.e. to burn completely and eliminate forest fuels)
	Select cut small Doug fir (<20 cm dbh)	Tips age-structure to ppine dominant in long-term; assures all age classes represented in future Mimics low-intensity ground fire	Labor intensive Problem with removal or burning (increased fuels on forest floor) after cut Cutting trees currently against RNA policy
	Prescribed burn (no pre cut) low intensity fire	Natural process Would remove smallest Doug fir Would rejuvenate target grasses as well	Small Doug fir could provide ladder to canopy for fire Would also remove small Ponderosa pine (contrary to objective) Would not remove 5-20 cm dbh regenerating trees. This is the size-class currently out of proportion
	Plant only small pine	Tips age structure to ppine if seedlings survive Would add genetic diversity	Evapotranspiration control on growth makes survival difficult for planted seedlings Labor intensive; expensive unless done with volunteers Materials (seedlings) could be expensive; no guarantee of success for objective Increased competition for limited resources if add more trees to community
	No action		Threaten long-term integrity of RNA; shade-dominant trees prevail resulting in loss of target grasses and ppine
2. Reduce weedy species	**Spray select areas**	Rapid results	Application must be repeated every 3 years Expensive Unknown long-term effects on biodiversity Unknown long-term effects on wildlife/insects Residual in soil/ effect on soil microbes Possible bioresistance by weeds in long-term Affect water quality- runoff from steep slopes will have herbicides in water Treatment not "natural"
	Aerial spray entire RNA	Rapid results	Same as above. Greater water-quality risk, greater expense, greater risk to wildlife and long-term biodiversity Social problems with adjacent private land and livestock
	Biological control	Natural	May take too long to get results Prohibitively expensive at this time Will take many types to control the variety of weeds and noxious plants in RNA Unknown effects on biodiversity if insects target other hosts
	Hand pull	Rapid results Least disruptive	Expensive unless done with volunteer labor Area too large to make this practical Feasible only to get rid of noxious , not entire range of weedy species
	No action	None	Interspecific competition with bunchgrass, long-term loss of biodiversity

			Loss of RNA integrity
3. Reduce coarse woody debris in select areas	Pile and burn in slash pile	Easily controlled with minimum labor Can consolidate burning debris with burning cut trees Minimum time frame for surveillance of each individual fire/ safety	Sterilize soil if burn too hot Nutrients released on burning not distributed across savannah floor Widely scattered areas for crews to stack debris Benefits of burn limited to small area - minimal benefit to entire community for effort expended
	Burn in place in low-intensity ground fire	Distribute nutrients over large area Get burn effect on other understory vegetation Natural process	Risk loss of control on fire Needs more crew to control fire Small risk to large trees without advance prep (like removing litter from tree base) depending on timing of fire
	No action	Continued slow release of organic material to soil Home for insects, small animals, lichens	Continued buildup of forest fuels
4. Increase regeneration of p pine	**Burn understory**	Natural process Prepares mineral seed bed for seed germination Removes interspecific competition for seedlings	Present ppine producing little seed (cone-boring insect infestation) to seed mineral bed Will not be effective without control on wildlife browsing, which will decrease on burned areas but increase on non-burned and fire-rejuvenated areas Timing of burn critical. Need to have adequate moisture for seed germination as well as mineral bed Fire dangers same as ground fire for debris above
	Plant p pine seedlings	Gets seedlings past most vulnerable stage (i.e. moisture limiting) Can plant where most needed (i.e. plots with no 0-10 cm dbh trees)	Artificial means of increasing regeneration Evapotranspiration control on growth makes survival difficult for planted seedlings Labor intensive unless done with volunteers Materials (seedlings) could be expensive; no guarantee of success for objective Will not succeed without creating open environment (i.e. not shade tolerant) or planting in open
	Hand scatter ppine seed	Increase chance of regeneration Not labor intensive or expensive Can scatter where most needed	Artificial means of increasing regeneration May change genetic makeup of ppine in future if use seed not native to the area Seedbed still needs to be prepared (burned) Chances of survival same as above if seed bed not prepared, if shaded by other plants/trees or if moisture inadequate for survival
	No action	Natural succession process	Continued decrease of ppine in mixed-savannah unless get good seed year Will lose target vegetation if follow current successional trend to Doug fir

Table 6d: Alternatives for restoration in forest community

Objective	Alternatives	Advantages	Disadvantages
1. Preserve old-growth ppine	No action	Positive aesthetic/social value	Long-term risk from increased competition for limited resource
	Burn understory	Reduces competition for resources needed by old-growth	Needs preparation - remove litter/duff from under old-growth trees to prevent excess damage to roots Preparation labor intensive May cause too much trauma to old trees so high risk of mortality
2. Preserve old-growth Doug fir	Remove diseased trees	Controls spread of mistletoe? (broom-growth) to old-growth and younger	Against RNA policy unless disease is considered epidemic Problem eliminating downed trees once they've been cut
	Burn understory	Reduces competition for resources needed by old-growth	Needs preparation - remove litter/duff from under old-growth trees to prevent excess damage to roots Preparation labor intensive May cause too much trauma to old trees so high risk of mortality
	No action	Positive aesthetic/social value	Depends on rate of disease spread
3. Restore composition to p pine dominant	Select cut Douglas fir all ages in randomly selected areas	Mimics fire removal - non age specific Immediate changes in composition Immediate canopy coverage changes	Age structure now skewed to young Doug fir; large size classes already dominated by ppine No guarantee to meet objective Could jeopardize old-growth Douglas fir; random removal of any large-diameter trees could eliminate an age-class Threatening one of target vegetation types - (ie. Doug fir/ bunchgrass) Removal of large trees problematic (i.e. to burn completely and eliminate forest fuels) Removes thermal cover for wildlife Affects snow interception and overall soil moisture Cutting currently against RNA policy
	Select cut Doug fir 40 cm dbh or less	Tips age-structure to ppine dominant in long-term; assures all age classes represented in future Mimics low-intensity ground fire for removing small trees; Mimics natural process of fire removing mid-sized trees Removes trees that grew because of fire suppression Creates open canopy and understory Immediate changes in composition	Labor intensive Problem with removal or burning (increased fuels on forest floor) after cut Removes thermal cover for wildlife Affects snow interception and overall soil moisture Cutting trees currently against RNA policy
	Prescribed burn - no pre cut low intensity fire	Natural process Would remove smallest Doug fir Would rejuvenate target grasses	Small and mid-size Doug fir and shrubs (ninebark, serviceberry) provide ladder fuels to reach canopy Would also remove small Ponderosa pine (contrary to objective) Would not remove 5-30 cm dbh regenerating trees. This is the size-class

			currently out of proportion
	Plant only small pine	Tips age structure to ppine if seedlings survive. Would add genetic diversity	Evapotranspiration control on growth makes survival difficult for planted seedlings Labor intensive; expensive unless done with volunteers Materials (seedlings) could be expensive; no guarantee of success for objective Increased competition for limited resources if add more trees to community Won't survive if shaded by older Doug fir
	No action		Threaten long-term integrity of RNA; shade-dominant trees prevail resulting in loss of target grasses and ppine
4. Restore open structure to forest	Cut trees randomly - no regard for species, size, condition - to specified openness	Mimic natural process of fire Immediate results	Problem with removal of cut trees - slash pile, leave strewn on forest floor- all create fuel problems May lose some age classes with random method Labor intensive; need good cutting plan Cutting trees currently against RNA policy May endanger old-growth ppine with random selection method Reducing thermal cover for wildlife Affects snow interception and overall soil moisture
	Cut only Doug fir of specified sizes to specified basal area or percent coverage	Immediate effects on composition and structure Works with objective above (composition)	Problem with removal of cut trees - slash pile, leave strewn on forest floor- all create fuel problems Cutting trees currently against RNA policy Reducing thermal cover for wildlife Affects snow interception and overall soil moisture
	Prescribed burn- no pre cut	Natural process Would rejuvenate target grasses Burn pattern creates mosaic for biodiversity	Small and mid-size Doug fir and shrubs (ninebark, serviceberry) provide ladder fuels to reach canopy Would not remove 5-30 cm dbh regenerating trees. This is the size-class currently out of proportion Labor intensive to monitor fire for safety Long-term affect on aesthetics of forest Would also remove small Ponderosa pine (contrary to objective below)
	No action		Jeopardize target vegetation of RNA which needs open canopy; jeopardize integrity of RNA
5. Restore previously logged areas (eastern drainage)	Plant p pine seedlings	Gets seedlings past most vulnerable stage (i.e. moisture limiting) Can plant where most needed (i.e. plots with no 0-10 cm dbh trees) Opportunity to "restore" portion of RNA previously destroyed by man	Artificial means of increasing regeneration Evapotranspiration control on growth makes survival difficult for planted seedlings Labor intensive unless done with volunteers Materials (seedlings) could be expensive; no guarantee of success for objective Will not succeed without creating open environment (i.e. not shade tolerant) or planting in open
	Hand scatter ppine seed	Increase chance of regeneration Not labor intensive or expensive Can scatter where most needed	Artificial means of increasing regeneration May change genetic makeup of ppine in future if use seed not native to the area Seedbed still needs to be prepared (burned)

			Chances of survival same as above if seed bed not prepared, if shaded by other plants/trees or if moisture inadequate for survival
	Burn excess coarse woody debris	Return nutrients to soil Accelerate decomposition and decay	
	No action	Open acreage for grass and savannah	
6. Reduce coarse woody debris from select areas with high concentrations	Pile and burn in slash pile	Easily controlled with minimum labor Can consolidate burning debris with burning cut trees Minimum time frame for surveillance of each individual fire/ safety Fairly small quantity for crews to handle in Classes 1 to 4	Sterilize soil if burn too hot Nutrients released on burning not distributed across forest floor Widely scattered areas for crews to stack debris Benefits of burn limited to small area - minimal benefit to entire community for man-hours expended No revitalization of grasses and herbs in understory (i.e. jeopardize target vegetation)
	Burn in place in low-intensity ground fire	Distribute nutrients over large area Get burn effect on other understory veg. Natural process Burn patterns create mosaic for biodiversity	Abundant ladder fuels in many areas that increase risk of fire reaching into canopy Needs more crew to control fire Aesthetics altered for several years
	No action	Continued slow release of organic material to soil Home for insects, small animals, lichens	Continued buildup of forest fuels
7. Increase regeneration of p pine	**Burn understory**	Natural process Prepares mineral seed bed for seed germination	Present ppine producing little seed (cone-boring insect infestation) to seed mineral bed Will not be effective without control on wildlife browsing, which will decrease on burned areas but increase on non-burned and fire-rejuvenated areas Timing of burn critical. Need to have adequate moisture for seed germination as well as mineral bed Fire dangers same as ground fire for debris above
	Plant p pine seedlings	Gets seedlings past most vulnerable stage (i.e. moisture limiting) Can plant where most needed (i.e. plots with no 0-10 cm dbh trees)	Artificial means of increasing regeneration Evapotranspiration control on growth makes survival difficult for planted seedlings Labor intensive unless done with volunteers Materials (seedlings) could be expensive; no guarantee of success for objective Will not succeed without creating open environment (i.e. not shade tolerant) or planting in open
	Hand scatter ppine seed	Increase chance of regeneration Not labor intensive or expensive Can scatter where most needed	Artificial means of increasing regeneration May change genetic makeup of ppine in future if use seed not native to the area Seedbed still needs to be prepared (burned) Chances of survival same as above if seed bed not prepared, if shaded by other plants/trees or if moisture inadequate for survival
	No action		Continued decrease of ppine in forest unless get good seed year Will lose target vegetation if follow current successional trend to Doug fir

8. Preserve biodiversity long-term	**Cut and remove small Doug fir**	Controls future composition balance - prevents dominance by shade Creates natural gaps for gap dynamics Creates mosaic of patterns that promotes biodiversity and new plant establishment Retains old-growth and understory plants Can retain proper amount of canopy cover to protect present diversity Can control disease if diseased trees cut at same time	Problem eliminating downed trees once they've been cut Labor intensive No revitalization of understory that would get with burn
	Burn understory to remove small Doug fir (low-intensity ground fire)	Natural process Revitalize grasses under trees Fire easier to control in moist/cool Mosaic depends on burn pattern and timing Would eliminate coarse woody debris which occupies space for plants (i.e. increase potential for biodiversity)	Will eliminate some biodiversity in understory if fire too hot or timed incorrectly May endanger old-growth unless precautions taken (i.e. remove base litter from trees) Will not eliminate >5 cm dbh Doug fir (These are the regenerating trees) Will not control disease Fire will positively effect shrubs, which are current problem in riparian (see below) No control on future composition - eliminates both Doug fir & ppine alike Fire in riparian bottom difficult to get to burn anything
	Cut/burn small trees -random selection	Imitates natural burn characteristics (no age, size, or species preference)	Does not guarantee balance of ppine and Doug fir future composition Problem eliminating cut trees Does not guarantee preserved old-growth Does not guarantee shade environment for present or future biodiversity
	No action		Loss of biodiversity counter to both goals and objectives of RNA Doug fir will eventually control light and compete successfully for nutrients over ppine and other trees and shrubs in forest

Table 6e: Alternatives for restoration in riparian community

Objective	Alternatives	Advantages	Disadvantages
1. Preserve old-growth ppine	No action	Positive aesthetic/social value	Long-term decline (competition for resources)
2. Preserve old-growth Doug fir	Remove diseased trees	Controls spread of mistletoe? (broom-growth) to old-growth and younger	Against RNA policy unless disease is considered epidemic Problem eliminating downed trees once they've been cut
	No action	Preserves dense shade for riparian shade-loving understory plants Positive aesthetic/social value	Depends on rate of disease spread Long-term decline (competition for resources)
3. Preserve biodiversity long-term	Cut and remove small Doug fir to predetermined coverage or basal area	Controls future composition balance - prevents dominance by shade Creates natural gaps for gap dynamics Creates mosaic of patterns that promotes biodiversity and new plant establishment Retains old-growth and understory plants Can retain proper amount of canopy cover to protect present diversity Can control disease if diseased trees cut at same time	Problem eliminating downed trees once they've been cut Labor intensive May reduce understory shade required for present biodiversity No revitalization of understory as with burn Currently against RNA policy
	Burn understory to remove small Doug fir (low-intensity ground fire)	Natural process Revitalize grasses under trees Fire easier to control in moist/cool Mosaic depends on burn pattern and timing Would eliminate coarse woody debris which occupies space for plants (i.e. increase potential for biodiversity)	Will eliminate some biodiversity in understory if fire too hot or timed incorrectly May endanger old-growth unless precautions taken (i.e. remove base litter from trees) Will not eliminate >5 cm dbh Doug fir (These are the regenerating trees) Will not control disease Fire will positively effect shrubs, which are current problem in riparian (see below) No control on future composition - eliminates both Doug fir & ppine alike Fire in riparian bottom difficult to get to burn anything
	Cut/burn small trees -random selection	Imitates natural burn characteristics (no age, size, or species preference)	Does not guarantee balance of ppine and Doug fir future composition Problem eliminating cut trees Does not guarantee preserved old-growth Does not guarantee shade environment for present or future biodiversity Currently against RNA policy Labor intensive;
	No action		Doug fir will eventually control light and compete successfully for nutrients over ppine and other trees and shrubs in riparian area
4. Reduce dense tangle of understory shrubs and fallen trees at river	**Cut and remove portion of shrub mass and downed trees**	Improve access for human and wildlife Decrease fuel load in riparian forest Less trampling of plants at river edge by	Short-term improvement; shrubs grow more vigorous after pruning; Long-term increase biomass Labor intensive; cutting in shrubs with thorns and prickles (stinging nettle)

		people or wildlife (short-term?)	Will trample low-constancy plants to carry out this alternative
	Burn shrubs at river edge	Natural process of removal Natural fire breaks on both sides of removal (i.e. talus and water)	Fire too difficult to start in moist riparian Short-term improvement; shrubs grow more vigorous after burning (current, gooseberry, service berry, mock orange, ninebark); Long-term increase in biomass Fire can climb to canopy if get going with many shrub and tree levels forming ladder Removes other vegetation besides shrubs and downed trees (ie. high fire-susceptible plants) Burning in riparian area may be harmful to stream sediment loading and fish population
	No action		Affect access to water by larger wildlife and humans in long-term; continual increase in fuel load from dying trees & shrubs; continued trampling of plants as multiple paths are created through shrubs and downed trees by wildlife and people Long-term severe limitation of light to riparian floor

Preferred Alternatives for Restoration

Each of the five plant communities within Sawmill Creek will require special considerations and techniques to meet restoration goals.

Grassland

Short-term efforts to reduce interspecific competition between native grasses and weeds in the RNA (objective 2) should include herbicide spraying in areas that have particularly heavy concentrations of noxious weeds. Repeated treatments will be necessary because knapweed remains viable in the soil bank for over six years (Tyler and Key, 1988). The repeat application interval for Tordon is normally every three years (Missoula County extension service, personal communication). Herbicide treatment on the most concentrated weed infestations is presently underway in conjunction with research studies on weed response to Tordon and Stinger by Rice and others (1992) and Rice (1994). Herbicide treatments in the RNA will probably need to be extended to aerial spraying, possibly by helicopter Helicopter spray would be most practical because the terrain is quite steep, the area too large for hand application, and the method leaves no vehicle tracks or rutting in the sensitive grasslands (objective 7). Herbicides will not be a long-term solutions to the weed problems in the entire RNA, however. They do not meet the criteria of "naturalness." They will be fairly expensive to apply over the 100+ acres of grassland. They also require repetitive applications for long-term success with the danger of plant communities becoming immune to spraying. Most importantly, the long-term effects of herbicides on biodiversity, ecosystem function and wildlife are presently poorly understood for these community types.

Low-intensity spring or fall burning is recommended in grasslands following herbicide spraying. Burning will meet short-term objectives to restore natural processes (objective 1) and restore grassland habitat (objective 2). It will also increase yield and productivity of the bunchgrasses (objective 4; Redmann and other 1993) . The disadvantages of burning include short-term loss of mobile nitrogen and increased susceptibility of inorganic nitrogen to leaching (Dudley and Lajtha, 1993). The advantages include: "naturalness"; rejuvenation of native grassland plants (Mosley, 1990); increased biomass from grasses in years following the burn (Redmann and others, 1993); maximum destruction of above-ground

weeds; low maintenance costs (because of longer treatment interval); and minimal monetary costs for the area, manpower and supplies involved.

To protect the resiliency of the grasslands in the long-term, its biodiversity needs to be maintained (Tilman and Downing, 1994). The importance of maintaining species in grassland ecosystems was shown recently by Tilman and others (1996). Using field experiments, they showed that management practices that decrease local biodiversity threaten the productivity of a grassland ecosystem, the sustainability of nutrient cycling, and the stability of the overall system. Low-intensity fires will protect as many of the existing plants as possible to maintain this diversity. It also creates a mosaic of growing conditions within the burn area that promotes diversity because each area burns with different intensities and varies in recovery.

Several studies show that burning is beneficial to improve production and forage quality (objectives 4 & 5) of grassland plants (see Chapter 1 introduction, this paper). In bluebunch wheatgrass communities, specifically, burning caused increased protein concentrations in the herbage (Redmann and others, 1993). The adverse aesthetic and air-quality effects of burning are very short-term in this area (objective 7). The social and scientific effects on current research projects could be enhanced by evaluating the effectiveness of a combination of fire and herbicide treatment in the weed study plots. If burning is conducted on half of the grassland at a time, total loss of scientific studies would not be lost, and a comparison between burned and sprayed plots could enhance research studies. A similar combination of burning and herbicide treatments was applied by the Montana Department of Fish and Game to grasslands and shrublands of the Blackfoot-Clearwater Wildlife Management Area. According to Mike Thompson (1997), control of the spotted knapweed in the BCWMA is attributed to broadcast spray with Tordon, which eliminated knapweed as a direct competitor for resources needed by the grasses. The increased health and quantity of grass (mainly rough fescue) plants, however, was attributed to burning (Thompson, 1997).

The decision whether to burn in the spring or fall should be determined by ecological and economic conditions. Of the grasses specifically targeted for preservation in the RNA, Idaho and rough fescue are probably the most susceptible to fire-kill because of their morphology. The tightly-packed

growth form of the bunchgrass holds fire longer in the root culms than other types of grasses (Michell, 1958). Bluebunch wheatgrass, on the other hand, has an open morphology and is fairly resistant to burning, except after a dry year (Fischer and Bradley, 1987; Bailey and Anderson, 1978). According to Fischer and Bradley (1987), the least fire damage to all these grasses occurs using spring or fall fires when soil moisture is high and duff layers are moist and protected. In Sawmill Creek, these conditions occur in early spring or late fall. As mentioned in the situation statement (this chapter), spring burning should be initiated before the fescues, wheatgrass, and annual grasses begin actively growing otherwise resiliency is reduced and mortality is high (Bailey and Anderson, 1978, Rasmussen, 1992). Research by Bailey and Anderson (1978) and Redman and others (1993) also found that rough fescue was reduced using a spring burn. However, the plants usually recovered by the second season. Both studies found that spring burning either increased wheatgrass or the effects were unclear. Spring burning should also have a positive effect on cheatgrass reduction, which is a problem in grassland areas of Sawmill Creek RNA. Rasmussen (1992) found that prescribed burning could temporarily reduce cheatgrass for about two years following the burn. Because the effect isn't permanent and probably needs to be conducted later than is desirable for the bunchgrasses (i.e. early summer before the seeds have scattered), burning to reduce cheatgrass should be used as a top-removal technique to give competitive advantage to resprouting species and annuals with seed reserves in the soil (Rasmussen, 1992). The effect of burning on herbs and shrubs of the RNA would also be determined by their phenological growth stage, the fuel load adjacent to growing tissues and the moisture conditions at the time of the burn (Rasmussen, 1992). In general, the initial effects of grassland burning are an increase in herbs over grasses (Hensel, 1923; Bailey and Anderson, 1978). However, some grassland herbs, which contribute to biodiversity in this RNA, are also highly susceptible to fire, including heartleaf arnica (Fischer and Bradley,1987). Except for big sagebrush, shrubs are not significantly affected by either a spring or fall burn (Redman and others, 1993). The spread of big sagebrush onto the grassland can be naturally controlled with burning because it is susceptible to fire kill (Wright and Bailey, 1980; Fischer and Bradley, 1987). However, hand removal of any seed crop from the plants may be necessary prior to burning because the plants will recover from a good seed source (Fischer and Bradley, 1987). Economically, spring burning in the grasslands would also

be the most practical because it can be combined with prescribed burning in the forests. To burn the forests in the spring and the grasslands in the fall would require double expense and labor for similar yearly effect and few added advantages. The biggest advantage of burning grasslands in the fall would be to protect the early spring bunchgrasses dominated by C3 photosynthetic pathways (Redman and others, 1993), such as fescue, and to have a full year of grass growth for dry fuel load to carry a fire. The major disadvantage may be loss of control on the fire from the dry conditions and increased fire intensity to damage the bunchgrass root systems (Manitoba Environmental, 1996).

The return intervals for grassland burning seem to be controversial. Before settlement and the introduction of annual grasses like cheatgrass, Peters and Bunting (1994) suggest that fire-free intervals varied with location, vegetation present, and topography. In some areas, like the lower Snake River Plain, natural fires were not common. Return intervals ranged from 20-100 years, which allowed late-seral perennial sagebrush and bunchgrass to develop (Peters and Bunting, 1992). They suggest fire-free intervals of 10-12 years in annual grasslands after settlement, and 20-50 years to establish sagebrush communities (Peters and Bunting, 1992). Daubenmire (1942) also suggested that natural prairie fires were rare in the Palouse grassland, which includes portions of western Montana. According to Manitoba Environmentsl (1996), burning may be necessary every 5 to 10 years to diminish tree and shrub invasion but more frequent burns are not necessary to maintain a healthy grassland. They further state that 5 to 10 years is sufficient for maintenance of mixed and fescue prairie grasslands. Wright and Bailey (1980) also suggest that natural fire intervals of five to 10 years is not unreasonable. Redman and others (1993) showed that fescues recovered from burning within two or three years. Agropyron recovered within five years (Redman and others, 1993; Bailey and Anderson, 1978). Daubenmire (1942) also stated that fire affects the "moss-lichen synusia" in Festuca-Agropyron grasslands, which takes "at least several years to redevelop" (p. 74). Therefore, the minimum fire return interval recommended for this study is five years. Maintenance burns are recommended five to 10 years to control cheatgrass and invasion of shrubs and trees.

The problem of overgrazing bunchgrass and tree species should be addressed in restoration recommendations. Although the bunchgrasses are not in danger of elimination, high ungulate

populations are severely affecting their growth and reproduction. Both deer and elk use the area for browse. Ungulate populations should be reduced in the surrounding landscape by increasing hunting opportunities in surrounding Forest Service or private lands. If wildlife populations decline, rejuvenation and increased yield of grass plants should increase bunchgrass production in the long-term (McNaughton and others, 1988).

The aesthetic problem of plot markers littering the RNA grasslands will have to be controlled by RNA policy. Restoration recommendations would include reducing the size and visibility of the present plot markers on the RNA to improve aesthetics (objective 7) and limiting number and size in the future.

Shrub-dominated savannah

One small sage-dominated area on the northwest side of the RNA is less than two acres and is one of the most diverse communities in the RNA. It was also an historical part of the landscape in pre-settlement time. Therefore, it should be protected from destruction by catastrophic burning. In order to protect the habitat for bunchgrass growth, however, the spread of sagebrush from this area onto other areas of the grassland should be curtailed (objective 2). Therefore, the shrub-dominated savannah areas in the RNA should also be burned with the same frequent, low-intensity fire as the grassland.

Timing and intensity of burning in the sage-dominated area will have to be carefully done. To create a mosaic of conditions within the sage-dominated community on the northwest side, protect its biodiversity, and insure future seed sources, only small portions of the area should be burned at any one time. In other areas of shrub-dominated savannah, the widely-scattered sagebrush and juniper will need to be removed to fulfill objective 2. Recently, prescribed fire was moderately successful in restoring prairies in Glacier National Park, which has climate, vegetation and restoration goals similar to Sawmill Creek (Kurth and Benson, 1995). In the park, prescribed autumn fires successfully reduced tree encroachment on the grassland but did not eliminate sagebrush cover. According to Kurth and Benson (1995), sagebrush cover, once established, may only be removed under fire conditions hotter, drier, and more windy than a low-intensity autumn burn. Individual plants on that encroach on the grasslands may have to be removed by creating "hot spots" with artificially accumulated fuels on each plant to be

removed. There is little duff or coarse woody debris accumulated in this community, however, to make any portion of it burn hotter than surrounding grasslands.

Future spread of big sagebrush onto the grassland may also be curtailed by picking mature seeds from the plants for several consecutive years. This alternative may be moderately labor intensive, but not difficult work. Sagebrush seeds remain viable in the soil bank for about 4 years (ref**, 19**).

Mixed-tree and -shrub savannah

The critical objective in the mixed-tree and shrub savannah is to remove Douglas-fir trees less than 20 cm dbh, to restore ponderosa pine as the dominant species in this community. The preferred alternative to meet this objective in the short-term is to select-cut the Douglas-fir trees (Table 6c). Select cutting can mimic fire patterns and will also ensure that ponderosa pine composition is dominant in the community. Low-intensity burning alone will not remove the largest trees of this class and will kill both Douglas-fir and ponderosa pine trees. Select cutting is currently against RNA policy. It also results in downed trees that increase fuel load in this community. In many areas, it is impractical to gather these down trees into slash piles because the area is too large. Therefore, burning will be necessary to reduce or eliminate this fuel load (Table 6c). Burning is also necessary to reduce competition and prepare a seed bed for ponderosa pine seeds to germinate. Without bare mineral soil for ponderosa pine germination, the compositional makeup of this community will continue to favor Douglas-fir. Arno (1976) documented frequent, low-intensity surface fires in historical open-canopy, ponderosa-pine dominated environments like these returned at intervals of six to 10 years.

Where accumulation of litter and duff is great in this community, it may also be necessary to dig out and removed excess duff from trees targeted for preservation. This action is especially critical for preservation of old-growth trees (>60 cm dbh). Duff and litter should be removed from within the drip-line of the canopy of old-growth trees to prevent burning of fine, sensitive roots.

Canyon Forests

The accumulation of coarse woody debris, Douglas-fir trees and shrubs make the use of prescribed or natural fires in the RNA canyon forests very risky. 60 years of fire suppression created too much fuel on the ground and up into the canopy to introduce the natural process of fire without taking many precautions. Fire is necessary, however, to restore the structure and function of forest communities to conditions more in line with conditions that created and maintained them in pre-settlement time (Arno, 1996; objectives 1 & 3). Although silvicultural treatment is often preferred to recreate these conditions in many areas (Fiedler, 1996), cutting is not a preferred approach in the RNA because it violates the "naturalness" policy and social ideals for "natural or wilderness" aesthetics (objective 7). Each of the three drainages containing forests in the RNA are quite different in terms of fuel buildup and structure that needs repair. All require different techniques and intensities of restoration.

The westernmost drainage has burned in the past and needs low-intensity, spring or late fall fire only in selected areas to remove coarse woody debris and small Douglas-fir. Of the three drainages, it is the most similar to "pre-settlement" condition for these forests described by Arno (1980). It does, however, contain "pockets" of very dense Douglas-fir as a middle cohort, which probably came in after a fire. The Douglas-fir trees are so thick in the "pockets" that competition will naturally control their growth. However, they will also create dangerous ladder fuels if burning is not done carefully. The structure in this drainage consists of a fairly cool, closed-canopy forest with fescue, pinegrass, elk sedge, Douglas-fir and minor small shrubs in the understory. Low-intensity ground fires would protect forest species susceptible to fire-kill in the drainage including kinnickinick, pinegrass, and Idaho fescue (Fischer and Bradley, 1987). Because some acreage has experienced patchy natural fire already, only minimal area needs prescribed fire to control rocky mountain juniper and Douglas-fir regeneration, reduce class 4 coarse woody debris, restore pre-settlement structure (objective 3) and protect the aesthetics of the drainage (objective 7).

Restoring the natural processes of fire will be most difficult in the central, forked drainage. Abundant ninebark, current, serviceberry and juniper combine with dense "pockets" of middle-sized Douglas-fir on the east side of the middle drainage(s) to create dangerous burning conditions. A two-stage, multi-year restoration plan may be necessary for this drainage. If the aesthetic costs are deemed

appropriate to offset the risk of wildfire, an initial silvicultural treatment may be required to at least reduce the shrubs and small-sized Douglas-fir before introducing fire because most of the shrubs in this drainage are resistant to fire and come back even thicker after a moderate burn (Fischer and Bradley, 1987). However, silvicultural treatment will increase the fuel load on the ground and endanger herbs and grasses sensitive to fire-kill. Even though the majority of the plants in these forests are perennial, intense heat will kill their roots. Using silviculture treatment plus prescribed burning increases economic costs, but reduces wildfire risk, social risk (i.e. loss of forest community in this drainage) and aesthetic costs. The second stage of restoration treatment would remove the accumulation of coarse woody debris from the ground and eliminate Douglas-fir seedlings and junipers using low-intensity ground fires. Low-intensity burning, however, would not reduce shrub cover to create more open, park-like pre-settlement conditions (objective 3), increase regeneration by older ponderosa pine (objective 6) or reduce insect and disease populations. It would, however, protect the diversity and stability of the present forests, restore structure more correlative with pre-settlement structure, and minimally reduce the processes leading to degradation (goal 1) of forest structure and health. This drainage will require the most difficult decisions on whether "naturalness", economics, wildfire risk or policy issues take precedence in Sawmill Creek RNA restoration.

The easternmost drainage has experienced fairly extensive historical logging, which affects the upper 1/2 to 2/3rds of its pre-settlement acreage. The forests of this drainage primarily require low-intensity, spring or fall ground fire to reduce the surface downed woody debris, stumps and downed boles, which were created during the logging. Class 3 and 4 coarse woody debris dominates plots of the eastern drainage and totals more debris than both the western and central drainage plots combined. It is decaying very slowly on the southern slopes. Fires would return vital nutrients to the soil from the coarse woody debris and enhance the grasses and herbs of the savannah that presently comprises the upper eastern drainage. This drainage does have more regeneration of ponderosa pine than Douglas-fir in the logged, terraced area. After reintroducing fire to this drainage, artificial seeding of ponderosa pine might be beneficial to fulfill objective 6 and eventually restore open forests in this drainage to the acreage similar to pre-settlement (see 1937 photo, Figure 24).

According to Arno (1988), historical fire regimes for ponderosa pine forests in western Montana were typically low-intensity surface fires that burned large areas but killed few trees. Fires were frequent in both seral and climax forests (Morgan, 1994). Fire-frequency intervals ranged from one to 30 years (Arno, 1988). In similar ponderosa pine forests in the southwest, light surface fires returned naturally every two to 10 years (Sackett and others, 1995). Research on vegetative response to frequent fire in ponderosa pine forests of the southwest revealed a four-year return interval to maximize recovery of understory vegetation, minimize overstory damage, and effectively minimize fuel buildup (Sackett and others, 1995). After six years, fuels begin to accumulate to a point where fires are difficult to control and "may cause undesirable damage to the residual overstory" (Sackett and others, 1995, p. 57).

The main priority for introducing the natural process of fire into the forest communities is to protect the ecologic, social and economic values of the RNA. Some ecologic problems will not be solved with the historic, low-intensity fires prescribed in these recommendations. Ponderosa pine regeneration will not be increased if seeds and cones are destroyed by insects and trees are browsed by ungulates. Disease and insects will not be eliminated (which is conducive to present RNA policy). Shrub understory will not be effectively reduced to create an open, park-like setting. However, the risk of catastrophic crown fires would be reduced. Forest understory structures may eventually become more similar to pre-settlement times with repeated treatment. Forest diversity would be protected. Forest aesthetics would be only minimally degraded in the short-term. Ongoing scientific studies in the RNA can anticipate natural disturbance within minimal time frames. If repeated within a 5-10 year time frame, maintenance costs should be minimal and as natural as possible.

Riparian Forests

Restoration objectives in the riparian zone include reducing coverage of small Douglas-firs and reducing the dense tangle of shrubs and dead trees and shrubs at the river's edge.

Although reintroduction of fire is probably needed in this area, just as in the rest of the RNA, it is one of the most problematic areas to burn because of the requirements of the flora and the steep topography near the stream-side management zone. All of the herbs and some shrubs important to this

environment are susceptible to fire and require shade to flourish, including twinflower, sweet-scented bedstraw, western false Solomon's seal, and pyrola. Most require an undisturbed duff layer to survive in the community (Fischer and Bradley, 1987). The shrubs are mostly fire resistant and some, including alder, chokecherry (Morber and Miyanishi, 1995), and mock orange even increase in quantity and quality if burned (Fischer and Bradley, 1987). Burning in the streamside-management zone can increase erosion and sediment loading in the stream, which affects fish habitat.

For a number of reason, this study is not recommending that fire be reintroduced into the riparian area at this time. Few experiments have been conducted using fire as a restoration tool in the riparian zone. Until more is known about the effects of burning this sensitive area, a conservative approach (no action) is recommended in this study. Although there is coarse woody debris concentrated in this community for fuel, a lightening strike in the riparian zone will probably will not spread very far because of the cool, moist conditions. Likewise, lightening strikes in the talus areas will probably not find continuous fuels to spread very far. At the edge of the talus areas, however, lightening strikes will affect canyon forests (see recommendations above). Control of common mullein and common dandelion, which are the most common weeds, may require spraying isolated patches with herbicide if these weeds are deemed particularly troublesome.

Cutting and removing a portion of the shrubs at the river edge may eventually be required for a number of reasons. Cutting would improve access to the stream for both humans and animals. It would also improve light to the forest floor so that the area does not become too shaded and lose biodiversity. If access improves, some plant trampling in the riparian area by animals and humans would be eliminated. One alternative is to cutting portions of the shrubs along the river for improved access is to build a path at the creek's edge. However, a pathway is not recommended because it will concentrate foot traffic, contribute to erosion, create wider band of trampling than now exists, and destroy the "natural" aesthetics of the riparian zone (counter to objective 7).

In the long-term, Douglas-fir will have to be thinned from the riparian community to protect biodiversity. The method of removal will have to dictated by on-going studies, similar those being conducted by Arno (1996), which must determine the best ways to remove these trees with minimal effect

on Sawmill Creek, its aquatic flora and fauna, and the litter and duff layers. Cutting and stacking the trees into slash piles is impractical on the steep slopes of the riparian zone along Sawmill Creek. Burning the trees where they fall on the ground results in the same problems listed above, but with less control on fire intensity because there would be more fuel. Removing the trees during winter may be a possibility, but only from old logging roads on the south side of Sawmill Creek. Reopening these roads will result in additional impacts to the creek. In addition, the riparian area is too steep and too narrow for tractor access without severe harm to the riparian community. On the other hand, no action at all will result in several additional long-term problems (see Table 6e). Canopy closure by Douglas-fir will continue, Douglas-fir will continue to compete successfully for limited nutrients with other trees and shrubs, critical species will be lost because of competition and changing light conditions, and risks of catastrophic crown fires will increase because Douglas-fir trees of various sizes act as ladders to the crown..

Summary

Several alternatives exist for restoring the natural process of fire to Sawmill Creek RNA. The RNA is actually small enough that it is feasible to implement a prescribed burn and treat the entire area within a day using a helicopter and small crew (L. Anderson, personal communication). This action would be the most "natural", the most economical , and most aligned with policy directives for no silvicultural treatment in the RNA. One day of effort and expense repeated every 5 to 10 years would eventually open the canopy and restore vitality to the grasslands. This action, however, raises questions about how much the canopy actually would open and how quickly, how much weed infestation would increase in the entire RNA because of the radical disturbance, and how many critical species and old-growth trees would be lost in the process. A helicopter burn would not allow strict control on burn locations or assessments of necessary adjustments to meet the burn goals (L. Anderson, personal communication). Therefore, ecologically this action is probably too risky, especially for the RNA forests where fuels have built up during 60 years of fire suppression.

A second alternative is to burn the grasslands and use silvicultural treatments to imitate burning in the forest. This alternative would do little to revitalize the grasses and eliminate the small Douglas-fir

seedlings from the forests. It would rapidly create an open-canopy forest, but in the process would create an extreme fuel load on the forest floor that increases risk of catastrophic fire. Piling the slash from this action would be difficult over the large area and in the steep drainages. Burning the downed trees would certainly result in many large, partially burned logs littering the RNA forest floor. The grasslands could easily be burned within a day using hand-ignition techniques for maximum control on intensity and spread. However, the downed trees would be difficult to burn completely (L. Anderson, personal communication) and large, partially-charred boles would remain part of the RNA aesthetics for decades. These downed trees would be advantageous to small mammals for cover and travel corridors. However, the numbers and sizes that would have to be removed from the steep drainages to open the forest canopy would cover the forest floor, eliminate growing space and light for bunchgrasses and herbaceous growth, and make travel difficult for large mammals even after burning.

A third alternative for restoration of the RNA is a combination of the two above methods. A combination of methods is a more conservative approach to restoring fire in the RNA. It would accomplish the following: 1) burn limited acreage in both the forest and grassland to control intensity and destruction; 2) use silvicultural treatments to accelerate canopy opening and reduce ladder fuels; and 3) create a mosaic of growing conditions in various stages of burn recovery throughout the RNA. It also preserves large areas of the RNA if treatment goes awry. The RNA can be easily burned in two or three sections within two or three days (or years) if desired. Using hand-ignition methods, fire ecologists would have a high degree of control on the intensity and spread of the fires and could assess immediately if the fire was detrimental to objectives for either the forest or the grassland communities (L. Anderson, personal communication). Sawmill Creek is a valuable piece of real estate for posterity. It requires a more conservative approach when reintroducing fire than might be required on adjacent non-RNA lands, even though conservative methods may be more expensive and against current policy. In spite of the increased economic costs and policy problems associated with this alternative, it is the most ecologically feasible alternative for Sawmill Creek restoration.

Ecologically, the most important goal in the RNA is to create conditions that preserve not only the target vegetation but as much biodiversity within each community as possible in the long-term. The

best method of creating a variety of conditions that enhance biodiversity and protecting existing seed sources is to create a mosaic of growing conditions throughout the RNA. A mosaic is created naturally during the burn process when wet and dry areas burn with varying success. A mosaic is also created by varying the acreage and periodicity of the burns. This action plan calls for a conservative approach to restoring the natural process of fire in the RNA that protects seed sources, protects critical species and old-growth trees, and creates such a mosaic of growing conditions in the RNA by varying acreage and locations of prescribed burns over several years (see action plan, Chapter 4).

Sawmill Creek RNA will require careful active management to fulfill its objectives and to keep its plant communities preserved for all time. While the surrounding landscape undergoes succession, natural ecological processes and manipulation by man, Sawmill Creek must serve as a showcase for specific communities of species into perpetuity. The RNA must also remain visually free of any direct influence by man in the spirit of current RNA policy. To bring the structures and functions within the RNA more in line with what it is known to have possessed before man evoked fire suppression on the area, the natural process of fire must be restored in the RNA. However, to restore structure of the five communities, silvicultural treatment is also required. Minimizing the visual effects of tree cutting will require not only skillful cutting, but restoring fire as a natural process to clean the forest floor. Restoring fire will also reverse many of the processes that have "damaged" the RNA over the past 60 years, including poor health of some bunchgrass colonies, accumulation of coarse woody debris in the forests and riparian areas, and loss of a quarter of the grasslands to conifer trees and sagebrush. However, the timing and location of fire must be man's choosing. The area is too small and too close to private land on a landscape that has changed radically since pre-settlement times. A catastrophic, high intensity fire from lightening strikes during dry conditions today could destroy the target forest communities, endanger the fragile bunchgrass communities, and/or increase social and economic risks if spread to private land. Ecologically, restoring the process of fire would make these ecosystems as "self-perpetuating" as possible by mimicking the conditions of pre-settlement times when frequent, low-intensity fires shaped and controlled the landscape and its flora in this part of Montana. In the process, the main ecologic

restoration goal of maintaining quality and integrity of the valuable ecosystems in Sawmill Creek RNA in perpetuity is more closely met.

Chapter 4: Action Plan

Introduction

Restoring ecological balance at Sawmill Creek RNA will take active and aggressive management over the next few decades. This chapter provides a proposed plan for that management and a timeline to implement restoration.

The proposed action plan is divided into three phases that strive to restore grassland integrity and historical function and structure to the ponderosa pine forests of Sawmill Creek within 10 years (see Table 7). Upon completion of the initial phases, a maintenance phase is required to complete the restoration objectives. **Phase one** begins aggressive treatment of noxious weeds and tests the effects of burning on this particular grassland. It also prepares the soil to eventually restore a severely altered forest in the eastern drainage. This drainage was heavily logged in the past, and now requires weed treatment and seeding to begin restoration. If the grassland recovers well from burning, **phase two** strives to 1) reduce the sage and juniper coverage on the remaining portions of the grassland and savannah; 2) reverse the degrading process of tree and shrub invasion into these communities, which has occurred on both RNA and non-RNA lands (see Chapter 2); and 3) alter forest structure to favor ponderosa pine. **Phase three** is the most aggressive phase. It strives to open the canopy and restore historic ponderosa pine dominance in three drainages with silvicultural treatments and burning (Table 7). Since these drainages contain abundant shrubs, dog-hair Douglas-fir and coarse woody debris, this area will be a challenge to restore to open-canopy, ponderosa pine- dominated forest. It will also have substantially more fuel on the ground after cutting to intensify fire than any of the previous phases. Therefore, careful planning will be required to determine which trees should be removed to restore a diverse age-structure in the ponderosa pine trees.

Although burning all of the grassland in the RNA could be accomplished in one phase instead of two, the proposed plan stresses a conservative, two-stage approach to grassland restoration that retains seed sources and insect and animal habitat. It also allows more recovery time if burning goes awry or the ecosystems are not as resilient as anticipated. A two-phase approach creates highly-desired mosaics of recovery patterns on the grasslands to enhance biodiversity in these communities (see chapter 3).

Each phase of the proposed action plan also includes a preparation period and a burn period (Table 7). Preparation includes such activities as spraying for weeds, establishing additional monitoring plots, silvicultural treatments, and monitoring effects of previous treatments. See Table 7 for details.

Objectives

The treatment areas are outlined in Figure 26. The areas are divided, when possible, at ridges to make burning easier and more efficient (L. Anderson, personal communication). Each area has specific problems that need to be addressed during restoration. The specific objectives for each phase of Sawmill Creek RNA restoration include the following:

Phase 1 objectives for restoration:

1) Reduce concentrations of spotted knapweed, dalmation toadflax and sulphur cinquefoil in grassland and savannahs of RNA using herbicides prescribed by current research in Sawmill Creek (Rice and others, 1994). Areas A, B., C, D, G, and M.
2) Prepare soil bed in previously logged (terraced) area (Area G, approx. 15 acres) for broadcast seeding of ponderosa pine.
3) Begin revitalization of bunchgrass plants (Area A, approx. 50 acres). Area contains good mix of Idaho fescue, rough fescue and bluebunch wheatgrass (Losensky, 1987). Minimize mortality of target bunchgrasses and species key to grassland composition (specifically, arrowleaf balsamroot, lupine, paintbrush). See Chapter 1 for key species list. Burning should be initiated before spring growth of fescues to minimize damage to roots and shoots of bunchgrass (Redman and others, 1993).

4) Begin restoration of small area of mixed-tree savannah to test response of community to underburn (Area D, approx. 10 acres). Reduce understory Douglas-fir seedlings and trees < 20 cm dbh by at least 75%. Minimize ponderosa pine mortality in overstory to <10%.

(PHASE 1: TOTAL BURNED= 75 ACRES)

Phase 2 objectives for restoration:

1) Continue weed control in areas that won't be burned in this phase (see Table 7).
2) Begin opening canopy in forest (Areas B and H, approx. 45 acres). Minimize ponderosa pine loss from cutting process. Down trees across slope. Use techniques that create minimal ecologic disturbance and minimal visual impact from human intervention.
3) Begin reconstruction of eastern drainage (Area G, approx. 15 acres). Broadcast seed area.
4) Reintroduce fire to remaining grassland (Area C, approx. 65 acres) to revitalize bunchgrasses if recovery of phase 1 grassland burning meets objectives. Minimize mortality to target bunchgrasses and species key to grassland composition (Area C). See Chapter 1 for specific key species.
5) Reduce sage and juniper cover on grassland (Area C) by 50 to 75%, if possible. This objective **DOES NOT** include area M.
6) Begin reintroduction of fire into sage-dominated savannah (Area M) to control spread of shrubs and remove Douglas-fir. Maximize Doug-fir mortality (100%) in <20 cm dbh size classes (see Figure 11b). **Burn only a portion of this area** (1/3?, approx. 1 acre) in phase 2 to protect seed sources of unique herbs in this community. Minimize loss of key herbs and grasses in this community (see Chapter 1 for key species).

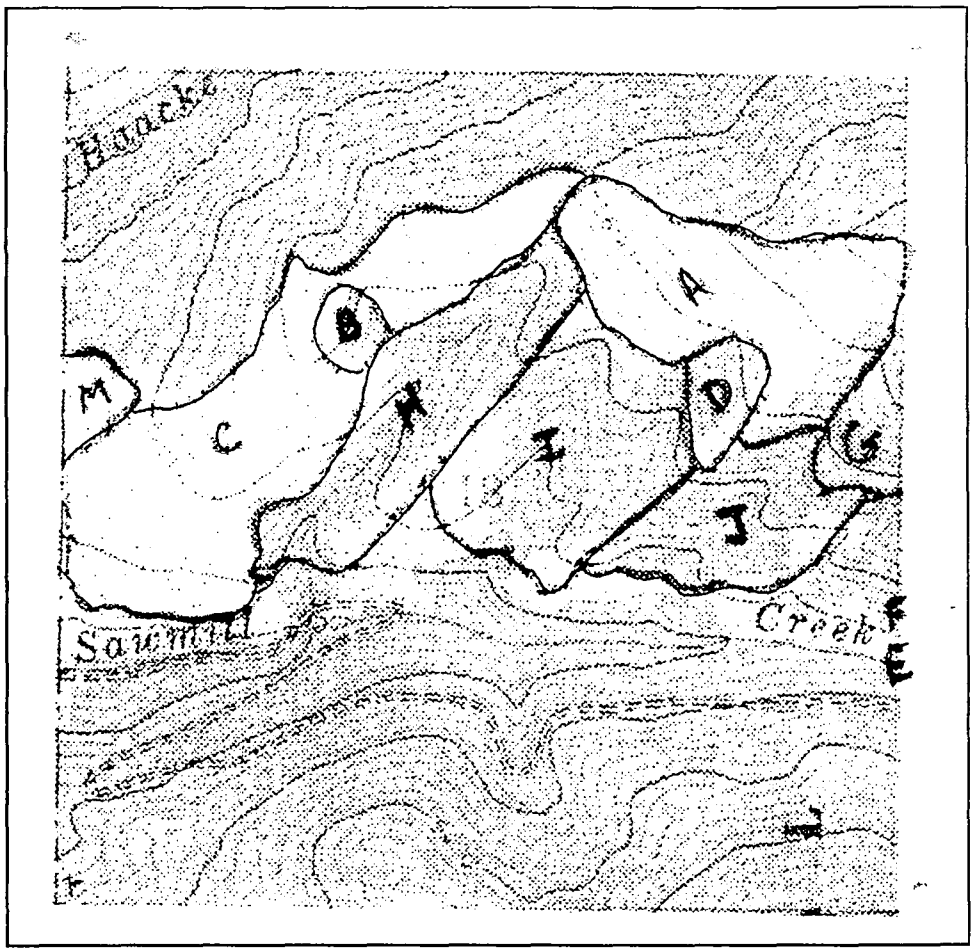


Figure 26: **Treatment areas for restoration plan**

7) Reintroduce natural process of fire to forest (Areas H and B). Reduce understory Douglas-fir seedlings by at least 75%. Reduce Douglas-fir trees (< 40 cm dbh) by at least 75% (see Figure 11d). Minimize ponderosa pine mortality in overstory to <10%. Minimize old-growth loss.

(PHASE 2: TOTAL BURNED = 110 ACRES)

Phase 3 objectives for restoration:

1) Open the forest canopy in three remaining drainages (Areas I and J, approximately 75 acres). Reduce understory Douglas-fir seedlings by at least 75%. Reduce overstory Douglas-fir trees (< 40 cm dbh) by 75% (see Figure 11d). Reduce Rocky Mountain juniper in understory by at least 50% (Figure 11d). Minimize ponderosa pine mortality in overstory to <10%. Minimize old-growth loss.
2) Reburn mixed-tree savannah (Area D, 10 acres). This burn **tests the effects of more frequent burning on the RNA savannah (i.e. four-year frequency).** The effects of this burn can be used to guide adaptive management decisions in maintenance phase. See Table 7 for Area D burn frequency.

(PHASE 3: TOTAL BURNED = 85 ACRES)

Objectives for maintenance phase in restoration:

1) Retain open structure created during restoration in forests.
2) Reverse process of invasion of trees and shrubs on grasslands.
3. Revitalize grass and herb plants at regular intervals.
4) Control fuel buildup in RNA.
5) Have regular interval for natural process of fire to affect RNA at time and intensity of man's choosing.
3) Monitor effects of restoration on permanent study plots for required changes in restoration plan (adaptive management.

Discussion

Burn areas for each phase are approximately 100 acres, which requires one-day of burning using on-ground techniques and a small crew (L. Anderson, personal communication). Helicopter burning is not recommended (see Chapter 3). Areas requiring silvicultural treatment (Areas H, I, and J) may require one or two days of cutting, depending on crew size. Logging crews should be sensitive to natural aesthetics of the RNA and to the philosophy of leaving as little visual impact from their activities as

possible. Best management practices (BMPs) should guide treatments prescribed for the riparian zone (Area E). No action is recommended in this study for areas of steep talus (area F) beside the riparian zone.

After the initial objectives are accomplished, the action plan outlines a 10-year maintenance program that would be repeated for at least the next two decades (Table 7) . The proposed maintenance phase calls for burn return intervals of five years for the grasslands and 10 years for the forest communities based on return intervals for each community . The maintenance phase also requires continual monitoring of permanent plots established in this study to evaluate the response of each community to burning in each treatment area (i.e. should the interval be lengthened or shortened, or more or less intense)..

Adaptive management philosophy should guide all restoration efforts in the RNA because it is difficult to scientifically prescribe restoration plans for three decades into the future without knowing results of initial prescriptions. The proposed restoration plan starts conservatively to test responses of each community to burning, herbicides and cutting. Phase 1 tests grassland response to burning in this particular RNA without exposing all the RNA grassland to disturbance at once. If objectives are met, phase 2 begins more aggressive restoration efforts in the grassland. It also begins forest restoration in areas that are already fairly open from historical logging and fire. Therefore, phase 2 is also a cautious test of cutting to restore open structure to the forests. If the canopy can be open sufficiently to promote bunchgrass development under the trees **and the downed trees can be effectively removed** (or significantly reduced) with burning, then phase three can be initiated. The results of phase two should give silviculturalists and fire ecologists a better idea of what to expect in this phase under the particular climate and ecological conditions of the RNA. Decisions on implementing phase three should be guided by the success or problems in phase two. Research is currently being conducted on the best way to restore open-canopy structure to these dense forests (Fiedler and others, 1995; Taylor, 1995). This research, and others like it, should guide techniques for opening the three drainages in phase three. In addition, more time may be required between phases than the allotted two years if recovery from restoration treatments is not satisfactory or climatic conditions are undesirable to initiate treatments (i.e. drought).. Only land

managers who continually monitor ecological changes in the permanent plots will be able to judge these needs and adapt the action plan accordingly.

In the maintenance phase, adaptive management should also play a prominent role in deciding if the burning and weed-treatment intervals called for in this plan are aggressive enough. The preferred option in the maintenance phase is to burn the grasslands on a five-year interval and the forests on a ten-year interval based on current knowledge of fire intervals in grasslands and forests of the Rocky Mountain west. Again, this is a conservative plan to allow maximum recovery of the communities between treatments. It is also the most financially frugal plan available to accomplish the objectives of this restoration within a small RNA budget. However, some current research calls for much more aggressive action to keep the ponderosa pine forests open once the silvicultural treatments are complete. In addition, vigilant monitoring is essential to determine if the frequency of the maintenance treatments in this schedule need to be adjusted or intensified. As researchers begin to learn more about the most effective burning intervals to perpetuate ponderosa pine forests and grasslands in other areas, Sawmill Creek's burn frequency may require adjustment to fit that knowledge. Specifically, some research suggests that a four-year burn frequency may be needed to maintain the open canopy and enhance regeneration in ponderosa pine forests of the west (Sackett and others, 1995). If this action is deemed necessary from current research and from monitoring permanent plots in the RNA (especially plot 19, Area d), a second option is presented with this plan for burning both the grasslands and the forests on a five-year rotation (Table 8). This option effectively doubles the effort and expense of maintenance, but may be essential to obtain the open-canopy desired in the forests to perpetuate the understory bunchgrasses and regenerate the ponderosa pine in the long-term.

This study recommends a slow and cautious approach to restoration. Recommendations on logging and burning and on the priority of treatment and recovery criteria are as conservative as possible. This conservative approach will ensure that parts of the RNA can act as seed source and that a mosaic of recovery patterns is created for biodiversity in the RNA. It may turn out that the plan is too conservative in some areas. One such area may be fire-return intervals for forests. However, there are difficulties in applying research data from other areas, such as ponderosa pine communities in the southwest United

States, to the particular communities of the RNA. Only land managers can determine if efforts are too conservative or too radical and adapt future treatments accordingly. In addition, there are still gaps in data for Sawmill Creek, especially on spring ephemerals. We don't know the full range of spring ephemerals and how they might be affected by burning recommendations. Sawmill Creek RNA is a very valuable piece of real estate for future education, research and community protection. Without restoration, these communities will not survive in perpetuity. With careful restoration and adaptive management, we can create conditions that ensure their survival and fulfill the establishment objectives for this particular RNA..

Table 7: Proposed Action Plan for Sawmill Creek Restoration

Objective	Phase 1		Phase 2		Phase 3	
	1997	1998	1999	2000	2001	2002
1) Reduce weed coverage	Spray weeds areas with herbicide a,b,c,d,g, m			Spray weeds a,d,g with herbicide		
2) Revitalize grasslands, reduce sage coverage	Begin consultation w/MDFWP to reduce deer population	**Burn area a**	monitor area a (12,13,14,15,20)			
Revitalize grasslands, reduce sage/juniper coverage			monitor area c	**Burn area c**	monitor area c (2,5.6.7,9.10)	
		hand-pick sage seeds area m	hand-pick sage seeds area m	**Burn small portion area m (1/3?)**	monitor area m	
3) Reduce Douglas-fir in mixed-tree savannah and canyon forest	Establish perm. Plot area b (#?) Remove duff and litter from base of all trees > 60 cm dbh area d	**Burn area d**	monitor area d(19)	**Burn area b**	monitor area b (#?)	**Burn area d**
4) Restore eastern drainage to ppine		**Burn area g**	monitor area g(24) Broadcast ppine seed over area g			
5) Open canopy in closed forest			Remove duff and litter from base of all trees > 60 cm dbh area h Cut area h using on-going studies to determine cut	**Burn area h**	Remove duff and litter from base of all trees> 60 cm dbh area i,j Monitor area h(18,32) Cut areas i,j using on-going studies to determine cut	**Burn area i,j**
6) Maintain unique communities(m, k)					monitor area m(3,4,8) for spread of sage	

** **Numbers in parenthesis ( ) indicate permanent plots established in this** study (see figure 2, Chapter 1).

Table 7 (continued): Proposed Action plan for Sawmill Creek restoration - maintenance phase

Objective	Maintenance									
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1) Reduce weed coverage	Spray weeds if necessary									
2) Revitalize grasslands, reduce sage coverage			monitor area a	**Burn area a**	monitor area a			monitor area a	**Burn area a**	monitor area a
Revitalize grasslands, reduce sage/juniper coverage		monitor area c monitor area m	**Burn area c** **Burn small portion area m (1/3?)**	monitor area c monitor area m			monitor area c monitor area m	**Burn area c** **Burn small portion area m (1/3?)**	monitor area c monitor area m	
3) Reduce Douglas-fir in mixed-tree savannah	monitor area d	monitor area b	**Burn area b** monitor area d (19)	**Burn area d** monitor area b	monitor area d		monitor area b	**Burn area b** monitor area d	**Burn area d** monitor area b	monitor area d
4) Restore eastern drainage to ppine				**Burn portion of area g**	monitor area g Broadcast ppine seed if necessary in recent burn area					
5) Open canopy in closed forest	monitor area i,j(21,22,23,26, 33)						monitor area h Remove duff and litter from base of all trees> 60 cm dbh area h Cut area h using on- going studies to determine cut	**Burn area h**	monitor area h monitor area i,j Remove duff and litter from base of all trees> 60 cm dbh area i,j Cut area i,j using on- going studies to determine cut	**Burn area i,j**
6) Maintain unique communities(m, k)	monitor area e (28,29, 30,31) for spread of Doug fir & shrubs	Cut area e according to ongoing research in riparian areas - doug fir only	Burn riparian if cutting required previous year??							

Table 8: Proposed Action Plan for Sawmill Creek Restoration - alternate maintenance phase (5-year rotation for both grasslands and forests)

Objective	Maintenance									
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1) Reduce weed coverage	Spray weeds if necessary									
2) Revitalize grasslands, reduce sage coverage	Burn area a	monitor area a			monitor area a	Burn area a	monitor area a			
Revitalize grasslands, reduce sage/juniper coverage		monitor area c monitor area m	Burn area c Burn small portion area m (1/3?)	monitor area c monitor area m			monitor area c monitor area m	Burn area c Burn small portion area m (1/3?)	monitor area c monitor area m	
3) Reduce Douglas-fir in mixed-tree savannah	monitor area d (19)	monitor area b	Burn area b monitor area d	monitor area d monitor area b	Burn area d	monitor area d	monitor area b	Burn area b	monitor area b monitor area d	Burn area d
4) Restore eastern drainage to ppine					Burn portion of area g	monitor area g Broadcast ppine seed if necessary in recent burn area				
5) Open canopy in closed forest	monitor area i,j (21,22,23,26,33)	monitor area h	Burn area h	monitor area h monitor area i,j	Burn area i,j	monitor area i,j	monitor area h Remove duff and litter from base of all trees > 60 cm dbh area h Cut area h using on going studies to determine cut	Burn area h	monitor area h monitor area i,j Remove duff and litter from base of all trees > 60 cm dbh area i,j Cut area using on- going studies to determine cut	Burn area i,j
6) Maintain unique communities(m, k)	monitor area e (28,29, 30,31) for spread of	Cut area e according to ongoing research	Burn riparian if cutting required previous year??							

REFERENCES CITED

Alden, W. C., 1953, Physiography and glacial geology of western Montana and adjacent areas. USGS Professional Paper 231, 200p.

Alt, D.D., and Hyndman, D.W., 1986, Roadside geology of Montana. Mountain Press, Missoula, Montana, 427 p.

Arno, M.K., 1996, Reestablishing fire-adapted communities to riparian forests in the ponderosa pine zone *in* Hardy, C.C., Arno, S.F., eds., The use of fire in forest restoration. Gen. Tech. Rep. INT-GTR-341. Ogden, Ut: U.S., Department of Agriculture, Forest Service, Intermountain Research Station, p. 42-43.

Arno, S.F, 1976, The historical role of fire on Bitterroot National Forest. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. Research Paper INT-187.

Arno, S.F., 1980, Forest fire history in the northern Rockies. Jour. For. 78(8): 460-465.

Arno, S.F., 1988, Fire ecology and its management implications in ponderosa pine forests *in* Baumgartner, D.M., and Lotan, J.E., ed., Ponderosa pine: the species and its management; symposium proc., Sept. 29-Oct. 1, 1987, Spokane, WA: Wash. State Univ. Coop. Extension publ, 133-140.

Arno, S.F., 1996, The concept: Restoring ecological structure and process in ponderosa pine forests *in* Hardy, C.C., Arno, S.F., eds., The use of fire in forest restoration. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah Gen. Tech. Rep. INT-GTR-341, p. 37-38.

Arno, S.F., and Brown, J.K., 1989, Managing fire in our forests - time for a new initiative. Jour. For. 87(12):44-46.

Arno, S.F., Reinhardt, E.D., and Scott, J.H., 1993, Forest structure and landscape patterns in the subalpine lodgepole pine type, a procedure for quantifying past and present conditions: GT Rept. Int-294, __ p.

Arno, S.F., and Scott, J.H., 199*, Structure of old-growth ponderosa pine stands on dry and moist sites as influenced by past fires: Can. Jour. For. Res., (*****have in-press copy).

Barber, , 19**, (constancy reference)

Bedunah, D.J., 1992, The complex ecology of weeds, grazing and wildlife. Western Wildlands, summer, p. 6-11.

Biswell, H.H., Kallander, H.R., Komarek, R., Vogl, R.J., and Weaver, H., 1973, Ponderosa fire management. Misc. Publ. 2. Tall Timbers Research Sta., Tallahassee, Florida, 49p.

Bradley, J., 1995, Political considerations of park and wilderness management *in* Brown, J.K., Mutch, R.W., Spoon, C.W., and Wakimoto, R.Hl, tech coord., Proceedings: symposium on fire in wilderness and park management, March 30-April 1, 1993, Missoula, MT, US Dept. Agriculture Forest Service General Technical Report INT-GTR-320, p. 6-8.

Brown, J.K., Arno, S.F., Bradshaw, L.S., Menakis, J.P., 1995, Comparing the Selway-Bitterroot fire program with presettlement fires *in* Brown, J.K., Mutch, R.W., Spoon, C.W., and Wakimoto, R.Hl, tech coord., Proceedings: symposium on fire in wilderness and park management, March 30-April 1, 1993, Missoula, MT, US Dept. Agriculture Forest Service General Technical Report INT-GTR-320, p. 48-54.

Caldwell, M.M., Richards, J.H., Manwaring, J.H., and Eissenstat, D.M., 1987, Rapid shifts in phosphate acquisition show direct competition between neighboring plants. Nature 327, 615-616.

Callaway, R.M., and Davis, F.W., 1993, Vegetation dynamics, fire, and the physical environment in coastal central California. Ecology 74(5):1567-1578.

Carlson, C. E., Arno., S., Pfister, R.D., Jones, J.G., Lyon, L.J., Kempf, M., 1994, Bitterroot Ecosystem Management/ Research Project Master Study Plan, unpublished, 17p.

Collins, S.L., and Wallace, L.L., 1990, eds., Fire in North American tallgrass prairies. Univ. Okla. Press, Norman. 175p.

Curry, Norbert, 1995, Bitterroot National Forest Stevensville Ranger District, personal communication. May 1996.

Daly, G.C., 1993, Social constraints on restoration ecology *in* Saunders, D.A., Hobbs, and Ehrlich, P.R., eds., Nature Conservation 3: Reconstruction of fragmented ecosystems - global and regional perspectives, Surrey Beatty & Sons PTY Limited, Norton, NSW, p. 9-16.

Daubenmire, R.F., 1968, Ecology of fire in grasslands. Adv. Ecol. Res. 5: 209-266.

Dudley, J.L., and Lajtha, K., 1993, The effects of prescribed burning on nutrient availability and primary production in sandplain grasslands. Am. Midl. Nat. 130 (Oct), 286-298.

Fiedler, C.E., 1996, Silvicultural applications: Restoring ecological structure and process in ponderosa pine forests *in* Hardy, C.C., Arno, S.F., eds., The use of fire in forest restoration. U.S., Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah, Gen. Tech. Rep. INT-GTR-341, p. 39-40.

Habeck, J.R., 1994, Using general land office records to assess forest succession in ponderosa pine/douglas-fir forests in western Montana. Northwest Science 68(2), 69-78.

Habeck, J.R., Joyner, C., Glevanik, J.D., Jolly, D.F., and Lassen, L.E., 1992, USDA Forest Service establishment record for Sawmill Creek Research Natural Area within Bitterroot National Forest Ravalli County, Montana, unpublished, 20p.

Harris, G.A., 1967, Some competitive relationships between Agropyron spicatum and Bromus tectorum. Ecological Monographs 37: 89-111.

Hill, M.O., and Gauch, H.G., Jr., 1980, Detrended correspondence analysis: An improved ordination technique. Vegetatio 42, 47-58.

Hitchcock, C.L., and Cronquist, A., 1973, Flora of the Pacific Northwest an illustrated manual. University of Washington Press, Seattle, Washington, 730p.

Husari, S.J., 1995, Fire management in small wilderness areas and parks *in* Brown, J.K., Mutch, R.W., Spoon, C.W., and Wakimoto, R.Hl, tech coord., Proceedings: symposium on fire in wilderness and park management, March 30-April 1, 1993, Missoula, MT, US Dept. Agriculture Forest Service General Technical Report INT-GTR-320, p. 117-120.

Johnson, J., USDA Forest Service Draft Sawmill Research Natural Area Management Plan, unpubl., 18p.

Jolly, 1995, Challenge address: Fire in wilderness and park management *in* Brown, J.K., Mutch, R.W., Spoon, C.W., and Wakimoto, R.Hl, tech coord., Proceedings: symposium on fire in wilderness and park management, March 30-April 1, 1993, Missoula, MT, US Dept. Agriculture Forest Service General Technical Report INT-GTR-320, p. 3-5.

Keen, F.P., 1943. Ponderosa Pine Tree Classes Redefined. Jour. Forestry V41(April), p. 249-253.

Knapp, A.K., and Seastedt, T.R., 1986, Detritus accumulation limits productivity of tallgrass prairie. BioScience 36: 662-668.

Kurth, L.L., and Benson, N.C., 1995, Prescribed fire in two prairies in the north fork of the Flathead River valley of Glacier National Park *in* Brown, J.K., Mutch, R.W., Spoon, C.W., and Wakimoto, R.Hl, tech coord., Proceedings: symposium on fire in wilderness and park management, March 30-April 1, 1993, Missoula, MT, US Dept. Agriculture Forest Service General Tecknical Report INT-GTR-320, p. 219-225.

Lackschewitz, K., 1991, Vascular plants of west-central Montana - identification guidebook. US Dept. Of Agriculture Forest Service, General Technical Report INT-277, 648p.

Losensky, B.J., 1987, Figure 4 (map): Forest and grassland habitat types of Sawmill Creek Research Natural Area in Establishment record for Sawmill Creek Research Natural Area within Bitterroot National Forest, Ravalli County, Montana, unpublished, 22 p.

Manitoba Environmental, 1996, Grassland management: Chapter 3 Conserving Grasslands - management considerations; internet address www.mb.doe.ca/ENGLISH/LIFE/WHP/PROGRASS/chp3.htm/, Nov. 28, 1996.

McCune, B., 1993, Multivariate analysis on the PC-Ord system. Oregon State University, Corvallis, Oregon.

McNaughton, S.J., Ruess, R.W., and Seagle, S.W., 1988, Large mammals and process dynamics in grassland ecosystems. BioScience 38: 794-800.

Microsoft Corporation, 1996, Microsoft Office Excel, computer software.

Morgan, P., 1994, Chapter 5: Dynamics of ponderosa and jeffrey pine forests in Hayward, G.D., and Verner, J., eds., Flammulated boreal and great gray owls in the United States: A technical conservation assessment. USDA Forest Service Rocky Mountain Experiment Station GTR RM-253, p. 47-73.

Morton, S., 1995, Meeting wilderness goals: A wilderness specialist's perspective *in* Brown, J.K., Mutch, R.W., Spoon, C.W., and Wakimoto, R.Hl, tech coord., Proceedings: symposium on fire in wilderness and park management, March 30-April 1, 1993, Missoula, MT, US Dept. Agriculture Forest Service General Technical Report INT-GTR-320, p. 34-37.

Mueller-Dombois, D., and Ellenburg, H., 1974. Aims and methods of vegetation ecology: New York, John Wiley & Sons, 547 p.

Neeckels, J., 1995, Wilderness and park fire policies and programs: vision of the future *in* Brown, J.K., Mutch, R.W., Spoon, C.W., and Wakimoto, R.H., tech coord., Proceedings: symposium on fire in wilderness and park management, March 30-April 1, 1993, Missoula, MT, US Dept. Agriculture Forest Service General Technical Report INT-GTR-320, p. 139-141.

Peet, 1974**, Shannon-weaver index

Pfister, R.D., Kovalchik, B., Arno, S., and Presby, R., 1977, Forest habitat types of Montana. USDA Forest Service General Tech. Rept. INT-34, 174p.

Pyne, S.J., 1995, Vestal fires and virgin lands: a reburn *in* Brown, J.K., Mutch, R.W., Spoon, C.W., and Wakimoto, R.Hl, tech coord., Proceedings: symposium on fire in wilderness and park management, March 30-April 1, 1993, Missoula, MT, US Dept. Agriculture Forest Service General Technical Report INT-GTR-320, p. 15-21.

Rasmussen, G.A., 1994, Prescribed burning considerations in sagebrush annual grassland communities *in* Monsen, S.B., and Kitchen, S.G., eds., Proceedings - ecology and management of annual rangelands. USFS Int. Research Station Gen. Tech. Rept. 313, p. 69-70.

Redman, R.E., 1978, Plant and soil water potentials following fire in a northern mixed grassland. J. Range Manage. 31:443-445.

Redmann, R.E., Romo, J.T., and Pylypec, B., 1993, Impacts of burning on primary productivity of *Festuca* and *Stipa-Agropyron* grasslands in central Saskatchewan. Am. Midl. Nat. 130: 262-273.

Rice, P., Burns, S., and Vance, D., 1994, Draft Summary of mapping data for ten targeted exotic forbs at the Sawmill Creek Research Natural Area, unpubl, 6p.

Rice P.M., Bedunah, D.J., and Carlson, C.E., 1992, Plant community diversity after herbicide control of spotted knapweed. USDA Forest Service Res. Paper INT-460, Inter. Res. Station, Ogden, UT , 6 p.

Ross, C.P., Andrews, B.A., Witking, I.J., 1955, Geologic map of Montana. Washington, DC: U.S. Department of the Interior Geological Survey, scale 1:500,000?.

Sackett, S.S , Haase, S.M., and Harrington, M.G., 1995, Lessons learned from fire use for restoring southwestern ponderosa pine ecosystems in Covington, W., and Wagner, P.K., eds., Conference on adaptive ecosystem restoration and management: Restoration of cordilleran conifer landscapes of North America, USDA Forest Service Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, General Technical Report RM-GTR-278, p.54-61.

Saunders, D.A., Hobbs, R.J., and Ehrlich P.R., 1993, Reconstruction of fragmented ecosystems: problems and possibilities *in* Saunders, D.A., Hobbs, and Ehrlich, P.R., eds., Nature Conservation 3: Reconstruction of fragmented ecosystems - global and regional perspectives, Surrey Beatty & Sons PTY Limited, Norton, NSW, p. 305-313.

Stankey, G., and McCool, S.F., 1995, Evolving conceptions of wilderness: Implications for the management of fire *in* Brown, J.K., Mutch, R.W., Spoon, C.W., and Wakimoto, R.H., tech coord., Proceedings: symposium on fire in wilderness and park management, March 30-April 1, 1993, Missoula, MT, US Dept. Agriculture Forest Service General Technical Report INT-GTR-320, p. 9-14.

Thomas, J.W., Anderson, R.G., Maser, C., and Bull, E., 1979, Snags *in* Thomas, J.W., eds., Wildlife habitats in managed forests in the Blue Mountains of Oregon and Washington. USDA Agr. Handbook no 553, Washington, D.C., p. 60-77.

Thompson, M., 1997, wildlife biologist, Department of Fish and Game on the Blackfoot-Clearwater Wildlife Management Area, personal communication, January 10, 1997.

Tilman D., and Downing J.A., 1994, Biodiversity and stability in grasslands. Nature 367, 363-365.

Tilman, D., Wedin, D., and Knops, J., 1996, Productivity and sustainability influenced by biodiversity in grassland ecosystems. Nature 379, 718-721.

Tyser, R.W., and Key, C.H., 1988, Spotted knapweed in natural area fescue grasslands: an ecological assessment. Northwest Science, 62(4), 151-160.

U.S. Department of Agriculture Forest Service, 1977, Corley Gulch, Montana, topographic map scale 1:24000.

Veseth, R., and Montagne, C., 1980, Geologic parent materials of Montana Soils. Montana Agricultural Experiment Station and USDA Soil Conservation Service Bulletin 721, Bozeman, Montana, , p. 19-24 and 89-91.

Whisenant, S.G., and Uresk, D.W., 1989, Burning upland mixed prairie in Badlands National Park. Prairie Nat. 21: 221-227.

Wilkinson, L., 1988. SYSTAT: The system for statistics. SYSTAT., Inc., Evanston, IL.

Wright, H.A., and Bailey, A.W., 1980, Fire ecology and prescribed burning in Great Plains - a research review. USDA Forest Service Tech. Rept. INT 77, Inter. For. Range Exp. Station., Ogden, Utah, 61p.

Wright, H.A., and Bailey, A.W., 1982, Fire ecology, United States and Southern Canada: New York, John Wiley and Sons, 501p.

Appendix A: Plants collected in Sawmill Creek RNA

FAMILY	GENUS	SPECIES	CODE	COMMON NAME	DATE	COLLECTOR	IDENTIFIER	FORM	GROWTH	SOURCE
Aceraceae	Acer	glabrum Torr.	ACGL	Rocky Mountain Maple	25-Jun-95	P. & K. Sikkink	Pam Sikkink	t	Per	Nat
Apocynaceae	Apocynum	androsaemifolium var. pumilum Gray	APAN	Creeping Dogbane	09-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Apocynaceae	Apocynum	canadinum L.	APCA	Common Dogbane		P. Sikkink	P. Sikkink	h	Per	Nat
Berberidaceae	Berberis	repens Lindl. (Mahonia repens (Lindl.)G. Don)	BERE	Oregon Grape	01-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Betulaceae	Alnus	incana (L.) Moench	ALIN	Thin-leaved Alder, Gray Alder	04-Jul-95	P. & K. Sikkink	Pam Sikkink	t	Per	Nat
Boraginaceae	Cryptantha	affinis (Gray) Greene + nutlets	CRAF	Slender Cryptantha	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Nat
Boraginaceae	Cryptantha	ambigua (Gray) Greene	CRAM	Obscure Cryptantha	03-Jul-95	P. Sikkink	P. Sikkink	h	Ann	Weed
Boraginaceae	Cryptantha	interrupta (Greene) Pays. (C. spiculifer (Piper)Pa	CRIN	Bristly Miner's Cradle	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Boraginaceae	Cynoglossum	officinale L.	CYOF	Hound's Tongue	09-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Intro
Boraginaceae	Lappula	redowskii (Hornem.) Greene	LARE	Western Stickseed	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Nat
Boraginaceae	Lithospermum	ruderale (Dougl.)	LIRU	Wayside Gromwell, Puccoon		P. Sikkink	P. Sikkink	h	Per	Intro
Boraginaceae	Mertensia	ciliata (Torr.) G. Don	MECI	Mountain Bluebells	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Boraginaceae	Mertensia	oblongifolia (Nutt.) G. Don	Meob	Leafy bluebells	25-May-96	P. Sikkink	P. Sikkink	h	Per	Nat
Boraginaceae	Myosotis	micrantha Pall	MYMI	Slender Forget-me-not	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Intro
Caprifoliaceae	Linaea	borealis L.	LIBO	Twinflower	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Caprifoliaceae	Lonicera	utahensis Wats.	LOUT	Red Twinberry, Utah Honeysuckle	09-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Caprifoliaceae	Sambucus	cerulea Raf.	SACE	Blue Elderberry	04-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Caryophyllaceae	Arenaria	congesta Nutt. var. lithophila Rydb	ARCO	Ballhead Sandwort	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Caryophyllaceae	Cerastium	arvense L.	CEAR	Field Chickweed	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Caryophyllaceae	Cerastium	nutans Raf.	CENU	Nodding Chickweed		P. Sikkink	P. Sikkink	h	Ann	Weed
Caryophyllaceae	Cerastium	vulgatum L..	CEVU	Mouse-ear Chickweed	04-Jul-95	P. Sikkink	P. Sikkink	h	Bien	Weed
Caryophyllaceae	Dianthus	armeria L.	DIAR	Deptford Pink	10-Aug-95	P. Sikkink	P. Sikkink	h	Bien	Intro
Caryophyllaceae	Silene	menziesii	SIME	Menzies Catchfly	03-Jul-95	P. Sikkink	P. Sikkink & P. Stic	h	Per	Nat
Caryophyllaceae	Symphoricarpos	albus (L.) Blake *flowers	SYAL	Common Snowberry	09-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Chenopodiaceae	Chenopodium	fremontii Wats.	CHFR	Fremont's Goosefoot	01-Jul-95	P. Sikkink	P. Sikkink	h	Ann	Nat
Chenopodiaceae	Chenopodium	leptophyllum (Moq.) Wats.	CHLE	Slim-leaf Goosefoot		P. Sikkink	P. Sikkink	h	Ann	Nat
Compositae	Achillea	millefolium L. var. lanulosa (Nutt.) Piper	ACMI	Yarrow, Milfoil	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Anaphalis	margaritacea (L.) B.&N.	ANMA	Pearly Everlasting	09-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Antennaria	microphylla Rybb. (A. rosea Greene)	ANMI	Rosy Pussytoes	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Arnica	cordifolia Hook.	ARCO	Heartleaf Arnica	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Arnica	latifolia Bong.	ARLA	Mountain Arnica	09-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Arnica	sororia Greene	ARSO	Twin arnica	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Artemesia	dracunculus	ARDR	Green sagewort, wild tarragon		P. Sikkink	P. Sikkink	h	Per	Nat
Compositae	Artemesia	frigida (Willd.)	ARFR	Fringed sagewort	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Artemisia	tridentata Nutt.	ARTR	Big Sagebrush	25-Jun-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Compositae	Aster	campestris Nutt. var campestris	ASCA	Western Meadow Aster		P. Sikkink	P. Sikkink	h	Per	Nat
Compositae	Aster	campestris Nutt. var. bloomeri Gray	ASCA	Western Meadow Aster		P. Sikkink	P. Sikkink	h	Per	Nat
Compositae	Aster	conspicuus Lindl.	ASCO	Showy Aster		P. Sikkink	P. Sikkink	h	Per	Nat
Compositae	Balsamorhiza	sagittata (Pursh) Nutt.	BASA	Arrowleaf balsamroot	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Carduus	nutans L.	CANU	Musk Thistle, Nodding Thistle		P. Sikkink	P. Sikkink	h	Bien	Weed
Compositae	Centaurea	maculosa Lam.	CEMA	Spotted Knapweed	10-Aug-95	P. Sikkink	P. Sikkink	h	Per	Noxio
Compositae	Chrysanthemum	leucanthemum L.	CHLE	Oxeye Daisy		P. Sikkink	P. Sikkink	h	Per	Exoti
Compositae	Chrysopsis	villosa (Pursh) Nutt.	CHVI	Hairy Golden Aster	10-Aug-95	P. Sikkink	P. Sikkink	h	Per	Nat
Compositae	Chrysothamnus	nauseosus (Pall.) Britt.	CHNA	Rubber Rabbit brush, Gray Rabbit brush		P. Sikkink	P. Sikkink	s	Per	Nat
Compositae	Chrysothamnus	viscidiflorus (Hook.) Nutt.	CHVI	Green Rabbit-brush	09-Aug-95	P. Sikkink	P. Sikkink	s	Per	Nat
Compositae	Cirsium	arvense (L.) Scop.	CIAR	Canada Thistle		P. Sikkink	P. Sikkink	h	Per	Nat
Compositae	Cirsium	undulatum (Nutt.) Spreng.	CIUN	Wavy-leaf Thistle	10-Aug-95	P. Sikkink	P. Sikkink	h	Per	Nat
Compositae	Crepis	attrabarba Heller	CRAT	Slender Hawksbeard	01-Jul-95	P. Sikkink	P. Sikkink	h	Per	Nat
Compositae	Crepis	occidentalis Nutt.	CROC	Western Hawksbeard	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Erigeron	caespitosus Nutt.	ERCA	Tufted fleabane, Tufted daisy	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Erigeron	compositus Pursh	ERCO	Cutleaf Daisy	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Erigeron	divergens T. & G.	ERDI	Spreading Fleabane	10-Aug-95	P. Sikkink	P Sikkink	h	Per	Nat
Compositae	Erigeron	pumilus Nutt.	ERPU	Shaggy Fleabane	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Gaillardia	aristata Pursh.	GAAR	Blanket Flower	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Open
Compositae	Helianthus	nuttallii T.&G.	HENU	Nuttall's Sunflower	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Hieracium	canadense Michx.	HICA	Canadian Hawkweed		P. Sikkink	P. Sikkink	h	Per	Nat
Compositae	Hieracium	cynoglossoides Arv.-Touv.	HICY	Hound's Tongue Hawkweed	10-Aug-95	P. Sikkink	P. Sikkink	h	Per	Nat
Compositae	Lactuca	biennis (Moench.) Fern.	LABI	Tall Blue Lettuce		P. Sikkink	P. Sikkink	h	Ann	Weed
Compositae	Lactuca	serriola L.	LASE	Prickly Lettuce		P. Sikkink	P. Sikkink	h	Ann	Weed
Compositae	Machaeranthera	canescens (Pursh) Gray	MACA	Viscid Aster		P. Sikkink	P. Sikkink	h	Bien	Nat
Compositae	Prenanthes	sagittata (Gray) A.Nels	PRSA	Rattlesnake-root	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Senecio	canus Hook.	SECA	Silvery Groundsel	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Senecio	integerrimus Nutt.	Sein	Lambstongue groundsel	25-May-96	P. Sikkink	P. Sikkink	h	Per	Nat

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FAMILY	GENUS	SPECIES	CODE	COMMON NAME	DATE	COLLECTOR	IDENTIFIED	FORM	GROWTH	SOURCE
Compositae	Senecio	sphaerocephalus Greene	SESP	Mountain-marsh Butterweed	09-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Senecio	triangularis Hook.	SETR	Arrowleaf Groundsel	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Compositae	Solidago	missouriensis Nutt.	SOMI	Missouri Goldenrod	10-Aug-95	P. Sikkink	P. Sikkink	h	Per	Nat
Compositae	Sonchus	oleraceus L.	SOOL	Common Sow-thistle		P. Sikkink	P. Sikkink & P. Stic	h	Ann	Weed
Compositae	Tanacetum	vulgare L.	TAVU	Common Tansy	10-Aug-95	P. Sikkink	P. Sikkink	h	Per	Intro
Compositae	Taraxacum	officinale Weber	TAOF	Common Dandelion	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Weed
Compositae	Tragopogon	dubius Scop.	TRDU	Yellow salsify, (Goatsbeard)	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Bien	Intro
Crassulaceae	Cornus	stolonifera Michx.	COST	Red Osier Dogwood	01-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Crassulaceae	Sedum	lanceolatum Torr.	SELA	Lanceleaf stonecrop	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Crassulaceae	Sedum	stenopetalum Pursh	SEST	Wormleaf stonecrop	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Cruciferae	Alyssum	alyssoides L.	ALAL	Pale alyssum	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Weed
Cruciferae	Arabis	glabra (L.) Bernh.	ARGL	Tower mustard		P. Sikkink	P. Sikkink	h	Bien	Intro
Cruciferae	Arabis	hirsuta (L.) Scop.	Arhi	Hairy Rockcress	25-May-96	P. Sikkink	P. Sikkink	h	Bien	Nat
Cruciferae	Arabis	holboellii Hornem. var. cotlinsii(Fern.)Rotlins	ARHO	Holboell's Rockcress	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Bien	Nat
Cruciferae	Camelina	microcarpa Andrz.	CAMI	Hairy False Flax	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Weed/
Cruciferae	Descurainia	richardsonii (Sweet) Schultz	DERI	Mountain tansy mustard	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Weed
Cruciferae	Draba	nemorosa L.	Drne	Woods Draba	25-May-96	P. Sikkink	P. Sikkink	h	Ann	Nat
Cruciferae	Draba	stenoloba Ledeb	Drst	Slender draba	25-May-96	P. Sikkink	P. Sikkink	h	Ann	Nat
Cruciferae	Draba	verna	Drve	Vernal Whitlow-grass	05-Apr-96	P. Sikkink	P. Sikkink	h	Ann	Nat
Cruciferae	Erysimum	asperum (Nutt.) D.C.	Eras	Plains wallflower	25-May-96	P. Sikkink	P. Sikkink	h	Bien	Nat
Cruciferae	Erysimum	inconspicuum (Wats.) MacM.	ERIN	Small Wallflower		P. Sikkink	P. Sikkink	h	Bien	Nat
Cruciferae	Lepidium	campestre (L.) R. Br.	LECA	Field Peppergrass		P. Sikkink	P. Sikkink	h	Ann	Intro
Cruciferae	Sisymbrium	altissimum	SIAL	Jim Hill Mustard	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Weed
Cruciferae	Sisymbrium	loeselii L.	SILO	Tumblemustard	09-Aug-95	P. Sikkink	P. Sikkink	h	Ann	Weed
Cupressaceae	Juniperus	communis L.	JUCO	Common Juniper	04-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Cupressaceae	Juniperus	scopulorum Sarg.	JUSC	Rocky Mountain Juniper	25-Jun-95	P. & K. Sikkink	Pam Sikkink	t	Per	Nat
Cyperaceae	Carex	concoinnoides Mack.	CACO	Northwest Sedge		P. Sikkink	P. Sikkink	c	Per	Nat
Cyperaceae	Carex	geyeri Boott.	Cage	Elk sedge	29-Apr-96	P. Sikkink	P. Sikkink	c	Per	Nat
Cyperaceae	Carex	limnophila Herm.	CALI	Pond sedge	01-Jul-95	P. Sikkink	P. Sikkink & Jay Hal	c	Per	Nat
Cyperaceae	Carex	pachystachya Cham.	CAPA	Thick-headed sedge		P. Sikkink	P. Sikkink & Jay Hal	c	Per	Nat
Cyperaceae	Carex	stipata Muhl.	CAST	Sawbeak sedge	01-Jul-95	P. Sikkink	P. Sikkink & Jay Hal	c	Per	Nat
Cyperaceae	Carex	xerantica Bailey	CAXE	Dryland Sedge		P. Sikkink	P. Sikkink & Jay Hal	c	Per	Nat
Elaeagnaceae	Shepherdia	canadensis (L.) Nutt.	SHCA	Canada or Bitter Buffaloberry, Soapberry	04-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Equisetaceae	Equisetum	arvense L.	EQAR	Common Horsetail	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Nat
Equisetaceae	Equisetum	hymale L.	EQHY	Common Scouring Rush	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Ericaceae	Arctastaphylos	uva-ursi (L.) Spreng.	ARUV	Bearberry, Kinnikinnick	25-Jun-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Ericaceae	Pyrola	asarifolia Michx.	PYAS	Pink or alpine Wintergreen	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Ericaceae	Pyrola	minor L.	PYMI	Lesser Wintergreen, Lesser Pyrola	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Ericaceae	Pyrola	secunda L.	PYSE	Sidebells pyrola, one-sided wintergreen		P. Sikkink	P. Sikkink & P. Stic	h	Per	Nat
Funariaceae	Corydalis	aurea Willd.	COAU	Golden Corydalis		P. Sikkink	P. Sikkink & P. Stic	h	Bien	Nat
Gentianaceae	Gentiana	amarella L.	GEAM	Northern Gentian, Felwort	04-Jul-95	P. Sikkink	P. Sikkink & P. Stic	h	Bien	Nat
Geraniaceae	Geranium	viscosissium F. & M.	GEVI	Sticky Wild Geranium	01-Jul-95	P. Sikkink	P. Sikkink	h	Per	Nat
Gramineae	Agropyron	cristatum (L.) Gaertn.	AGCR	Crested Wheatgrass		P. Sikkink	P. Sikkink & P. Stic	g	Per	Intro
Gramineae	Agropyron	intermedium (Hogt) Beauv.	AGIN	Intermediate Wheatgrass		P. Sikkink	P. Sikkink & P. Stic	g	Per	Intro
Gramineae	Agropyron	spicatum (Pursh) Scribn. & Smith	AGSP	Bluebunch Wheatgrass	09-Jul-95	P. Sikkink	Angie Evenden	g	Per	Nat
Gramineae	Agrostis	interrupta L.	AGIN	Interrupted Bentgrass	09-Jul-95	P. Sikkink	Angie Evenden	g	Ann	Nat
Gramineae	Agrostis	scabra Willd.	AGSC	Tickle-grass		P. Sikkink	P. Sikkink & P. Stic	g	Per	Nat
Gramineae	Avena	fatua L.	Avfa	Wild oats	25-May-96	P. Sikkink	P. Sikkink	g	Ann	intro
Gramineae	Bromus	inermis Leys.	BRIN	Smooth Brome, Hungarian Brome		P. Sikkink	P. Sikkink & P. Stic	g	Per	Nat
Gramineae	Bromus	japonicus Thunb.	BRJA	Japanese Brome		P. Sikkink	P. Sikkink & P. Stic	g	Ann	Intro
Gramineae	Bromus	mollis L.	BRMO	Soft Brome		P. Sikkink	P. Sikkink & P. Stic	g	Ann	Intro
Gramineae	Bromus	tecturm L.	BRTE	Cheatgrass	09-Jul-95	P. Sikkink	Angie Evenden	g	Ann	Intro
Gramineae	Calamagrostis	canadensis var. robusta Vasey	CACA	Bluejoint Reedgrass		P. Sikkink	P. Sikkink	g	Per	Nat
Gramineae	Calamagrostis	montanensis (Scribn.) Scribn.	CAMO	Prairie Reedgrass		P. Sikkink	P. Sikkink & Angie E	g	Per	Nat
Gramineae	Calamagrostis	rubescens Buckl.	CARU	Pinegrass	09-Jul-95	P. Sikkink	Angie Evenden	g	Per	Nat
Gramineae	Elymus	glaucus Buckl.	ELGL	Blue Wild Rye		P. Sikkink	P. Sikkink & P. Stic	g	Per	Nat
Gramineae	Festuca	idahoensis Elmer	Feid	Idaho fescue	25-May-96	P. Sikkink	P. Sikkink	g	Per	Nat
Gramineae	Festuca	octoflora Walt.	FEOC	Six Weeks Fescue		P. Sikkink	P. Sikkink & P. Stic	g	Ann	Nat
Gramineae	Festuca	scabrella Torr.	FESC	Rough Fescue		P. Sikkink	P. Sikkink	g	Per	Nat
Gramineae	Glyceria	striata (Lam.) A. S. Hitchc.	GLST	Fowl Mannagrass	09-Jul-95	P. Sikkink	Angie Evenden	g	Per	Nat
Gramineae	Koeleria	cristata Pers.	KOCR	June Grass	09-Jul-95	P. Sikkink	Angie Evenden	g	Per	Nat
Gramineae	Phleum	pratense L.	PHPR	Timothy	09-Jul-95	P. Sikkink	Angie Evenden	g	Per	Intro
Gramineae	Poa	compressa	POCO	Canada Bluegrass		P. Sikkink	P. Sikkink & P. Stic	g	Per	Intro

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FAMILY	GENUS	SPECIES	CODE	COMMON NAME	DATE	COLLECTOR	IDENTIFIER	FORM	GROWTH	SOURCE
Gramineae	Poa	pratensis L.	POPR	Kentucky Bluegrass		P. Sikkink	P. Sikkink	g	Per	Intro
Gramineae	Poa	sandbergii Vasey	POSA	Sandberg's Bluegrass		P. Sikkink	P. Sikkink & P. Stic	g	Per	Nat
Gramineae	Stipa	comata Trin. & Rupr.	STCO	Needle and Thread		P. Sikkink	P. Sikkink	g	Per	Nat
Gramineae	Stipa	occidentalis Thurb.	STOC	Western Needlegrass		P. Sikkink	P. Sikkink & P. Stic	g	Per	Nat
Grossulariaceae	Ribes	cereum Dougl.	RICE	Wax or squaw currant		P. Sikkink	P. Sikkink	s	Per	Nat
Grossulariaceae	Ribes	hudsonianum Richards.	RIHU	Western or Northern Black Current		P. Sikkink	P. Sikkink	s	Per	Nat
Grossulariaceae	Ribes	lacustre (Pers.) Poir.	RILA	Swamp Gooseberry, Prickyly Gooseberry	04-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Grossulariaceae	Ribes	setosum Lindl. *need flowers	RISE	Missouri gooseberry		P. Sikkink	P. Sikkink	s	Per	Nat
Hydrangeaceae	Philadelphus	lewisii Pursh.	PHLE	Mockorange, Syringa	09-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Hydrophyllaceae	Phacelia	franlinii (R.Br.) Gray	PHFR	Franklin's phacelia		P. Sikkink	P. Sikkink & P. Stic	h	Bien	Nat
Hydrophyllaceae	Phacelia	hastata Dougl.	PHHA	Silverleaf Phacelia	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Hydrophyllaceae	Phacelia	linearis (Pursh) Holz.	PHLI	Sand Phacelia	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Nat
Hypericaceae	Hypericum	perforatum L.	HYPE	St. John's wort, Goatweed	10-Aug-95	P. Sikkink	P. Sikkink	h	Per	Noxio
Juncaceae	Luzula	parviflora (Ehrh.) Desv.	LUPA	Small-flowered Woodrush		P. Sikkink	Angie Evenden	h	Per	Nat
Labiatae	Prunella	vulgaris L.	PRVU	Self-heal, Heal-all	10-Aug-95	P. Sikkink	P. Sikkink	h	Per	Nat
Labiatae	Scutellaria	lateriflora L.	SCLA	Mad-dog Skullcap, Hoodwort		P. Sikkink	P. Sikkink	h	Per	Nat
Leguminosae	Astragalus	inflexus Dougl.	ASIN	Hairy Milkvetch	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Leguminosae	Astragalus	miser Dougl.	ASMI	Weedy Milkvetch	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Leguminosae	Astragulus	canadensis var. mortonii (Nutt.) Wats.	ASCA	Canada Milkvetch	09-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Leguminosae	Lupinus	argenteus Pursh	LUAR	Silvery Lupine	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Leguminosae	Lupinus	sericeus Pursh	LUSE	Blue-bonnet Lupine, Silky Lupine	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Leguminosae	Lupinus	wyethii Wats.	LUWY	Wyeth's Lupine	01-Jul-95	P. Sikkink	P. Sikkink	h	Per	Nat
Leguminosae	Trifolium	repens L.	TRRE	White clover		P. Sikkink	P. Sikkink	h	Per	Intro
Liliaceae	Allium	cernuum Roth.	ALCE	Nodding Onion	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Liliaceae	Brodiaea	douglasii Wats.	BRDO	Wild Hyacinth	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Liliaceae	Disporum	trachycarpum (Wats.) Benth. & Hook.	DITR	Wartberry, Fairy Bells	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Liliaceae	Fritillaria	pudica (Pursh) Spreng.	FRPU	Yellow bell	01-Jul-95	P. Sikkink	P. Sikkink	h	Per	Nat
Liliaceae	Smilacina	racemosa (L.) Desf.	SMRA	Western False Solomon's Seal	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Liliaceae	Streptopus	amplexifolius var. chalazatus Fassett.	STAM	Twisted-Stalk	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Liliaceae	Veratrum	viride Ait.	VEVI	Corn lily, False Hellebore	09-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Liliaceae	Zigadenus	venenosus Wats.	ZIVE	Death camas	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Loasaceae	Mentzelia	dispersa Wats. +seeds	MEDI	Small-flowered Blazing Star	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Nat
Onagraceae	Epilobium	augustifolium L.	EPAU	Fireweed		P. Sikkink	P. Sikkink	h	Per	Nat
Onagraceae	Epilobium	paniculatum Nutt. var. paniculatum	EPPA	Tall Annual Willow-herb		P. Sikkink	P. Sikkink	h	Ann	Weed
Onagraceae	Epilobium	watsonii var. occidentale (Trel.) Hitchc.	EPWA	Watson's willow-herb		P. Sikkink	P. Sikkink	h	Per	Weed?
Orchidaceae	Calypso	bulbosa (L.) Oakes	Cabu	Fairy slipper	25-May-98	P. Sikkink	P. Sikkink	h	Per	Nat
Orchidaceae	Goodyera	oblongifolia Raf.	GOOB	Western Rattlesnake Plaintain or Orchid		P. Sikkink	P. Sikkink	h	Per	Nat
Orchidaceae	Habenaria	dilatata (Pursh.) Hook.	HADI	White Bog Orchid	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Pinaceae	Pinus	contorta Dougl.	PICO	Lodgepole Pine	09-Jul-95	P. & K. Sikkink	K. Sikkink	t	Per	Nat
Pinaceae	Pinus	ponderosa Dougl.	PIPO	Ponderosa Pine, Western Yellowpine, Bull Pine	04-Jul-95	P. & K. Sikkink	K. Sikkink	t	Per	Nat
Pinaceae	Pseudotsuga	menziesii (Mirbel) Franco	PSME	Douglas-fir	01-Jul-95	P. & K. Sikkink	Pam Sikkink	t	Per	Nat
Plantaginaceae	Plantago	major L.	PLMA	Common or Nippleseed Plaintain		P. Sikkink	P. Sikkink	h	Per	Weed
Plantaginaceae	Plantago	patagonica Jacq.	PLPA	Indian-wheat	10-Aug-95	P. Sikkink	P. Sikkink	h	Ann	Nat
Polemoniaceae	Collomia	linearis Nutt.	COLI	Narrow-leaf Collomia		P. Sikkink	P. Sikkink	h	Ann	Nat
Polemoniaceae	Microsteris	gracilis (Hook) Greene	MIGR	Pink Microsteris	09-Jul-95	P. Sikkink	Angie Evenden	h	Ann	Nat
Polygonaceae	Eriogonum	umbellatum Torr var. subalpinum (Greene)Jones	ERUM	Sulfur Buckwheat	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Polygonaceae	Polygonum	aviculare L.	POAV	Doorweed, Dooryard Knotweed		P. Sikkink	P. Sikkink	h	Ann	Weed
Polygonaceae	Polygonum	douglasii Green.	PODO	Douglas knotweed, Mountain Knotweed	09-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Nat
Polygonaceae	Rumex	crispus L.	RUCR	Curly, sour or yellow dock		P. Sikkink	P. Sikkink	h	Per	Weed
Polypodiaceae	Athyrium	distentifolium Tell Sch.	ATDI	Alpine Lady Fern	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Polypodiaceae	Cysteropteris	fragilis (L.) Bernh.	CRFR	Brittle Bladder-fern		P. Sikkink	P. Sikkink	h	Per	Nat
Polypodiaceae	Dryopteris	austriaca (Jacq.) Woynar	DRAU	Mountain Wood Fern	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Polypodiaceae	Woodsia	oregana D.C. Eat.	WOOR	Woodsia		P. Sikkink	P. Sikkink	h	Ann	Nat
Portulacaceae	Lewisia	rediviva Porsh	LERE	Bitterroot	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Portulacaceae	Montia	perfoliata (Donn) Howell (Claytonia perfoliata Don	MOPE	Miners Lettuce	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Primulaceae	Dodecatheon	conjugens var. viscidum (Piper Mason)	DOCO	Desert or Prarie or Slimpod Shooting Star	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Ranunculaceae	Actaea	rubra (Ait.) Willd.	ACRU	Baneberry	01-Jul-95	P. Sikkink	P. Sikkink & P. Stic	h	Per	Nat
Ranunculaceae	Clematis	columbiana (Nutt) T.&G.	CLCO	Columbia Virgin's Bower	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Ranunculaceae	Delphinium	bicolor Nutt.	DEBI	Low Larkspur	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Ranunculaceae	Ranunculus	glaberrimus Hook.	Ragl	Sagebrush Buttercup	05-Apr-98	P. Sikkink	P. Sikkink	h	Per	Nat
Ranunculaceae	Ranunculus	macounii Britt.	RAMA	Macoun's Buttercup	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Ranunculaceae	Ranunculus	pennsylvanicus L.	RAPE	Bristly Buttercup	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Ranunculaceae	Ranunculus	uncinatus D. Don	RAUN	Little Buttercup	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat

Appendix A: Plants collected in Sawmill Creek RNA

FAMILY	GENUS	SPECIES	CODE	COMMON NAME	DATE	COLLECTOR	IDENTIFIER	FORM	GROWTH	SOURCE
Ranunculaceae	Thalictrum	occidentale Gray	THOC	Western Meadowrue	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Rosaceae	Amelanchier	alnifolia Nutt.	AMAL	Serviceberry, Saskatoon	04-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Rosaceae	Fragaria	vesca L. var bracteata (Heller) Davis	FRVE	Woods strawberry	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Rosaceae	Fragaria	virginiana Duchesne	FRVI	Blueleaf or Virginia Strawberry	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Rosaceae	Geum	macrophyllum Willd.	GEMA	Large-leaved Avens **need flowers		P. Sikkink	P. Sikkink	h	Per	Nat
Rosaceae	Geum	triflorum Pursh	GETR	Prairie Smoke, Old Man's Whiskers	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Rosaceae	Potentilla	glandulosa Lindl.	POGL	Sticky Cinquefoil	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Rosaceae	Potentilla	gracilis Dougl. var. elmeri (Rybd.) Jeps.	PLGR	Soft Cinquefoil ** Need flowers		P. Sikkink	P. Sikkink	h	Per	Nat
Rosaceae	Potentilla	recta L.	PORE	Sulphur Cinquefoil, Erect Cinquefoil		P. Sikkink	P. Sikkink	h	Per	Weed
Rosaceae	Prunus	emarinata (Dougl.) Walp.	PREM	Bitter cherry		P. Sikkink	P. Sikkink	s	Per	Nat
Rosaceae	Prunus	virginiana L.	PRVI	Chokecherry	04-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Rosaceae	Pysocarpus	malvaceus (Greene) Kuntze	PYMA	Ninebark	25-Jun-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Rosaceae	Rosa	woodsii Lindl.	ROWO	Wood"s Rose		P. Sikkink	P. Sikkink	s	Per	Nat
Rosaceae	Rubus	idaeus L.	RUID	Red Raspberry	04-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Bien	Nat
Rosaceae	Rubus	parviflorus Nutt.	RUPA	Thimbleberry	01-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Bien	Nat
Rosaceae	Sorbus	scopulina Greene	SOSC	Cascade Mountain Ash	25-Jun-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Rosaceae	Spirea	betulifolia Pall.	SPBE	White spirea		P. Sikkink	P. Sikkink	s	Per	Nat
Rubiaceae	Galium	aparine L.	GAAP	Cleavers Goose grass	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Rubiaceae	Galium	triflorum Michx.	GATR	Sweet Scented or Fragrant Bedstraw	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Salicaceae	Populus	tremuloides Michx.	POTR	Quaking or Trembling Aspen	04-Jul-95	P. & K. Sikkink	Pam Sikkink	t	Per	Nat
Salicaceae	Populus	trichocarpa T.&G.	TOTI	Black Cottonwood	04-Jul-95	P. & K. Sikkink	Pam Sikkink	t	Per	Nat
Salicaceae	Salix	bebbiana Sarg.	SABE	Bebb Willow	01-Jul-95	P. & K. Sikkink	Pam Sikkink	s	Per	Nat
Saxifragaceae	Heuchera	grossulariifolia Rydb.	HEGR	Gooseberry-leaved Alumroot	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Saxifragaceae	Lithophragma	parviflora (HOok.) Nutt.	LIPA	Small-flowered Fringecup	23-Jun-95	P. Sikkink	P. Sikkink & P. Stic	h	Per	Nat
Saxifragaceae	Saxifraga	occidentalis Wats.	Saoc	Western Saxifrage	26-May-96	P. Sikkink	P. Sikkink	h	Per	Nat
Scrophulariaceae	Castilleja	hispida var. hispida Benth.	CAHI	Harsh paintbrush	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Scrophulariaceae	Castilleja	linariaefolia Benth.	CALI	Wyoming Paintbrush	10-Aug-95	P. Sikkink	P. Sikkink	h	Per	Nat
Scrophulariaceae	Castilleja	lutescens (Greenm.) Rydb.	CALU	Yellowish paintbrush	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Scrophulariaceae	Collinsia	parviflora Lindl.	COPA	Blue-eyed mary	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Nat
Scrophulariaceae	Linaria	dalmatica (L.) Mill.	LIDA	Dalmatian Toadflax		P. Sikkink	P. Sikkink	h	Per	Nox.
Scrophulariaceae	Mimulus	guttatus DC.	MIGU	Yellow Monkey Flower	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Scrophulariaceae	Orthocarpus	tenuifolius (Pursh) Benth.	ORTE	Twin-leaved Owl Clover	04-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Ann	Nat
Scrophulariaceae	Pedicularis	contorta Benth.	PECO	Alpine Fernleaf	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Scrophulariaceae	Penstemon	albertinus Greene	PEAL	Albert's Penstemon	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Scrophulariaceae	Penstemon	diphyllus Rydb.	PEDI	Late Penstemon	10-Aug-95	P. Sikkink	P. Sikkink	h	Per	Nat
Scrophulariaceae	Penstemon	procerus Dougl.	PEPR	Little Penstemon	09-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Scrophulariaceae	Verbascum	blattaria L.	VEBL	Moth Mullein	10-Aug-95	P. Sikkink	P. Sikkink	h	Bien	Intro
Scrophulariaceae	Verbascum	thapsus L.	VETH	Common Mullein	10-Aug-95	P. Sikkink	P. Sikkink	h	Bien	Weed
Sellaginellaceae	Selaginella	densa Rydb.	Sede	Compact clubmoss	29-Apr-96	P. Sikkink	P. Sikkink	m		
Umbelliferae	Angelica	arguta Nutt.	ANAR	Sharptooth Angelica	09-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Umbelliferae	Lomatium	ambiguum (Nutt.) Coult. & Rose	LOAM	Wyeth's Biscuit root, Desert swale biscuit root	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Umbelliferae	Lomatium	dissectum (Nutt.) Math & Const.	LODI	Fern-leaved Lomatium	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Umbelliferae	Lomatium	triternatum (Pursh) Coult. & Rose	Lotr	Nine-leaf lomatium	26-May-96	P. Sikkink	P. Sikkink	h	Per	Nat
Umbelliferae	Musineon	vaginatum Rydb.	MUVA	Sheathed musineon	01-Jul-95	P. Sikkink	P. Sikkink	h	Per	Nat
Umbelliferae	Osmorhiza	chilensis H.&A.	OSCH	Mountain Sweetroot	25-Jun-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Umbelliferae	Peridridia	gairdneri (H. & A.) Math.	PEGA	Yampah	10-Aug-95	P. Sikkink	P. Sikkink	h	Per	Nat
Urticaceae	Urtica	dioica var. gracilius (Ait.) Seland	URDI	Stinging Nettle	01-Jul-95	P. & K. Sikkink	Pam Sikkink	h	Per	Nat
Valerianaceae	Valeriana	dolica L.	VADO	Mountain Valerian	09-Jun-96	P. Sikkink	P. Sikkink	h	Per	Nat
Violaceae	Viola	adunca Smith	VIAD	Western violet		P. Sikkink	P. Sikkink & P. Stic	h	Per	Nat
Violaceae	Viola	nephrophylla Greene.	Vine	Bog violet	26-May-96	P. Sikkink	P. Sikkink	h	Per	Nat
Violaceae	Viola	nuttallii Pursh	Vinu	Nuttall's violet	26-May-96	P. Sikkink	P. Sikkink	h	Per	Nat

Appendix B: Raw data on plot composition including all species found in plots

SPECIES	FAMILY	Common Name	GROWTH	ORIGIN	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33
PEAL	Scrophulariaceae	Albert's Penstemon	Per	Nat	2	0	0.5	0	0	0	0	0.5	0	0	1	0	0.5	0	0	0	0.5	0.5	0.5	0.5	1	0	0.5	0.5	0	0.5	1	0	0.5	0	0.5	0.5	0.5
PECO	Scrophulariaceae	Alpine Fernleaf	Per	Nat	0	0	0	0	0	0	0.5	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ATDI	Polypodiaceae	Alpine Lady Fern	Per	Nat	0.5	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0.5	0	0	0.5	0	0	0	0.5	0	0	0	0	0	1	0	0	0.5	0	0	0
BASA	Compositae	Arrowleaf balsamroot	Per	Nat	0.5	2	0.5	2	2	1	2	2	3	3	3	3	3	3	2	2	1	1	3	2	0.5	2	2	1	0	1	1	0	0.5	0	0	0	0.5
SETR	Compositae	Arrowleaf Groundsel	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0	0
ARCO	Caryophyllaceae	Ballhead Sandwort	Per	Nat	0.5	1	0.5	0.5	0	0.5	0	1	0	0.5	0.5	1	1	0	0.5	1	1	0	1	1	0	0	0.5	0.5	0	0.5	1	0	0	0	0	0	0
ACRU	Ranunculaceae	Baneberry	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARUV	Ericaceae	Bearberry, Kinnikinnick	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0.5	0	0
SABE	Salicaceae	Bebb Willow	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0
ARTR	Compositae	Big Sagebrush	Per	Nat	0	3	3	2	0	1	0	0.5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0
PREM	Rosaceae	Bitter cherry	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
LERE	Portulacaceae	Bitterroot	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POTI	Salicaceae	Black Cottonwood	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GAAR	Compositae	Blanket Flower	Per	Nat	0	0	0.5	0.5	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LUSE	Leguminosae	Blue-bonnet Lupine, Silky Lupine	Per	Nat	0	1	1	1	1	0.5	1	1	0.5	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
COPA	Scrophulariaceae	Blue-eyed mary	Ann	Nat	0.5	1	0.5	0.5	0	1	1	0	1	1	0.5	0	1	1	0	0.5	0.5	1	1	0.5	0.5	0.5	0.5	0.5	0	0.5	1	0	0.5	0	0	1	1
SACE	Caprifoliaceae	Blue Elderberry	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0
ELGL	Gramineae	Blue Wild Rye	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0.5	0.5	0.5	0.5	0	0
AGSP	Gramineae	Bluebunch Wheatgrass	Per	Nat	0	3	2	2	3	3	2	2	3	4	3	3	3	3	3	1	2	0.5	2	3	0.5	1	3	2	0	3	3	0	0	1	0.5	0	0
CACA	Gramineae	Bluejoint Reedgrass	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FRVI	Rosaceae	Blueleaf or Virginia Strawberry	Per	Nat	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0.5	0.5	0	0	0.5	0
VINE	Violaceae	Bog violet	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RAPE	Ranunculaceae	Bristly Buttercup	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0
CRIN	Boraginaceae	Bristly Miner's Cradle	Per	Nat	0.5	0	0	0	1	0.5	0.5	0.5	1	0.5	0	0.5	0	0.5	0	0	0.5	0	0	0.5	0	0	0.5	0.5	0	0.5	2	0	0	0	0	0	0
CYFR	Polypodiaceae	Brittle Bladder-fern	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POCO	Gramineae	Canada Bluegrass	Per	Intro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASCA	Leguminosae	Canada Milkvetch	Per	Nat	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHCA	Elaeagnaceae	Canada or Bitter Buffaloberry, Soapberry	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0
CIAR	Compositae	Canada Thistle	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	1	1	0	0	0	0
HICA	Compositae	Canadian Hawkweed	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SOSC	Rosaceae	Cascade Mountain Ash	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
BRTE	Gramineae	Cheatgrass	Ann	Intro	0	2	1	1	2	2	3	1	2	2	0.5	1	0	2	2	0	0.5	0.5	1	2	0.5	0	2	0.5	1	1	3	0	0	0.5	0	0	0.5
PRVI	Rosaceae	Chokecherry	Per	Nat	0.5	0	0	0	0.5	0	0	0	0	0	0	0	0.5	1	1	0	0.5	0	0	0	0	0	1	1	1	0	0	1	1	2	2	0	0
GAAP	Rubiaceae	Cleavers Goose grass	Per	Nat	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0.5	1	0.5	0	0	0.5	0	0	0	0	0.5	0	0.5	0.5	0.5	0.5
CLCO	Ranunculaceae	Columbia Virgin's Bower	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0
TAOF	Compositae	Common Dandelion	Per	Weed	0	0.5	0	0.5	0	0	0	0	0	0	0.5	0	0	0	0	0.5	0	0	0	0	0	0.5	0	0	0	0.5	0	0.5	0.5	0	0.5	0	0
APAC	Apocynaceae	Common Dogbane	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EQAR	Equisetaceae	Common Horsetail	Ann	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	2	0	0	0	0
JUCO	Cupressaceae	Common Juniper	Per	Nat	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VETH	Scrophulariaceae	Common Mullein	Bien	Weed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0.5	0	0.5	1	1	0	1	1	0.5	0	0
PLMA	Plantaginaceae	Common or Nipplesead Plaintain	Per	Weed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EQHY	Equisetaceae	Common Scouring Rush	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	2	0	0
SYAL	Caryophyllaceae	Common Snowberry	Per	Nat	0.5	0.5	0	0	0	0	0	0	0	0	1	0	0.5	0	2	0.5	0	1	1	0	2	2	0.5	2	0	2	0.5	1	2	0.5	2	2	1
SOOL	Compositae	Common Sow-thistle	Ann	Weed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TAVU	Compositae	Common Tansy	Per	Intro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sede	Saxifragaceae	Compact clubmoss	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VEVI	Liliaceae	Corn lily, False Hellebore	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
APAN	Apocynaceae	Creeping Dogbane	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0.5	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
AGCR	Gramineae	Crested Wheatgrass	Per	Intro	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RUCR	Polygonaceae	Curly, sour or yellow dock	Per	Weed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ERCO	Compositae	Cutleaf Daisy	Per	Nat	0.5	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LIDA	Scrophulariaceae	Dalmatian Toadflax	Per	Noxio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZIVE	Liliaceae	Death camas	Per	Nat	0	0	0.5	0.5	0	0	0	0.5	0	0.5	0.5	0.5	0.5	1	0.5	0.5	0	0	0	1	0.5	0	1	0.5	0	0	0	0	0	0	0	0	0
DIAR	Caryophyllaceae	Deptford Pink	Bien	Intro	0	0	0.5	0.5	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DOCO	Primulaceae	Desert or Prarie or Slimpod Shooting Star	Per	Nat	0	0.5	0.5	1	0	0.5	0	0.5	0	0.5	0	0.5	2	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POAV	Polygonaceae	Doorweed, Dooryard Knotweed	Ann	Weed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PSME	Pinaceae	Douglas-fir	Per	Nat	0	0	0	0	0	0	1	1	0	0	0.5	0	0.5	0	0.5	3	0	2	1	1	2	2	0.5	1	0	2	0	2	2	0	2	4	3
PODO	Polygonaceae	Douglas Knotweed, Mountain Knotweed	Ann	Nat	0.5	0	0.5	0.5	0.5	0	0	0.5	0	0.5	0.5	0.5	0	0.5	0.5	0.5	0.5	0	0.5	0.5	0	0.5	0.5	0	0	0.5	0	0	0	0	0	0	0
CAXE	Cyperaceae	Dryland Sedge	Per	Nat	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cage	Cyperaceae	Elk Sedge	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.5	0	0	0	0	2	3	0	0.5	0	0.5	0	0	0	0	0	0	0
Cabu	Orchidaceae	Fairy slipper	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LODI	Umbelliferae	Fern-leaved Lomatium	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0.5	1	0.5	0	0	0	0	0	0	0	0	0	0	0.5	1	0	0.5	0.5	0.5	0	0
CEAR	Caryophyllaceae	Field Chickweed	Per	Nat	0	0	0	0	0	0	0.5	0	0.5	0.5	0	0.5	0	0	0	0	0.5	0	0	0.5	0	0	0	0	0	0	1	0	0	0	0	0	0
LECA	Cruciferae	Field Peppergrass	Ann	Intro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EPAU	Onagraceae	Fireweed	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0.5	0.5	0
GLST	Gramineae	Fowl Mannagrass	Per	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.5	0.5	0	0
PHFR	Hydrophyllaceae	Franklin's phacelia	Bien	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
CHFR	Chenopodiaceae	Fremont's Goosefoot	Ann	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0.5	0.5	0.5	0.5	0	0	0	0	0.5	0	0	0	0.5	0	0	0
ARFR	Compositae	Fringed sagewort	Per	Nat	2	1	0.5	0.5	2	1	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
CDAU	Funariaceae	Golden Corydalis	Bien	Nat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0
HEGR	Saxifragaceae	Gooseberry-leaved Alumroot	Per	Nat	0	0	0.5	0.5	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0.5	0	0	0	0	0	0.5	0	0	1	1	0
CHVS	Compositae	Green Rabbit brush	Per	Nat	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARDR	Compositae	Green sagewort, wild tarragon	Per	Nat	2	0.5	0.5	1	1	0.5	0	0	0	0.5	0	0.5	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2	0	0	0.5	0	0	0

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Appendix B: Raw data on plot composition including all species found in plots

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Appendix B: Raw data on plot composition including all species found in plots

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Appendix C: Raw data from study plots including only species with constancy

SPECIES	Common Name	GROWTH	SOURCE	FORM	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33	Plots w/sp	20/80 Cut
PEAL	Albert's Penstemon	Per	Nat	h	2		05					05			1		05				05	05	05	05	1		05	05		05	1		05		05	05	05	18	1
ATDI	Alpine Lady Fern	Per	Nat	h	05				05		05							05			05				05						1			05				8	1
ARCO	Bellhead Sandwort	Per	Nat	h	05	1	05	05		05		1		05	05	1	1		05	1	1		1	1			05	05		05	1							19	1
ARTR	Big Sagebrush	Per	Nat	s		3	3	2		1		05							1									05									7	1
LUSE	Blue bonnet Lupine, Silky Lupine	Per	Nat	h		1	1	1	1	05	1	1	05									05								1								10	1
COPA	Blue-eyed mary	Ann	Nat	h	05	1	05	05		1	1		1	1	05		1	1		05	05	1	1	05	05	05	05	05		05	1		05		1	1	25	1
AGSP	Bluebunch Wheatgrass	Per	Nat	g		3	2	2	3	3	2	2	3	4	3	3	3	3	3	1	2	05	2	3	05	1	3	2		3	3				1	05		27	1
FRVI	Bluleaf or Virginia Strawberry	Per	Nat	h								05												05		05						05	05			05		6	1
CRIN	Bristly Mitter's Cradle	Per	Nat	h	05				1	05	05	05	1	05		05		05				05		05			05	05		05	2							15	1
BRTE	Chestgrass	Ann	Intro	g		2	1	1	2	2	3	1	2	2	05	1		2	2		05	05	1	2	05		2	05	1	1	3			05			05	25	1
PRVI	Chokecherry	Per	Nat	s	05				05								05	1	1		05						1	1	1			1	1	2	2			13	1
GAAP	Cleavers Goose grass	Per	Nat	h	05													05				05	1	05			05					05		05	05	05	05	11	1
TAOF	Common Dandelion	Per	Weed	h		05		05							05					05						05				05		05	05		05		9	1
VETH	Common Mullein	Bien	Weed	h															05								05		05	1	1		1	1	05			8	1
SYAL	Common Snowberry	Per	Nat	s	05	05									1		05		2	05		1	1		2	2	05	2		2	05	1	2	05	2	2	1	20	1
SOOL	Common Sow-thistle	Ann	Weed	h																																			
APAN	Creeping Dogbane	Per	Nat	h														05	05			05	1	1				1										6	1
ZIVE	Death camas	Per	Nat	h			05	05				05		05	05	05	05	1	05	05				1	05		1	05										14	1
DECO	Desert or Plains or Shinpod Shooting Star	Per	Nat	h		05	05	1		05		05		05		05	2			05		05																10	1
POCU	Douglas Knotweed, Mountain Knotweed	Ann	Nat	h	05		05	05	05			05		05	05	05		05	05	05			05	05		05	05			05								17	1
PSME	Douglas fir	Per	Nat	t							1	1			05		05		05	3		2	1	1	2	2	05	1		2		2	2		2	4	3	19	1
Carex	Elk Sedge	Per	Nat	g		1													1	05					2	3		05		05								6	1
LODI	Fern leaved Lomatium	Per	Nat	h													05	1	05											05	1		05	05	05			9	1
CEAR	Field Chickweed	Per	Nat	h							05		05	05		05					05			05							1							7	1
CHFR	Fremont's Goosefoot	Ann	Nat	h															05			05	05	05	05					05			05					7	1
ARFR	Fringed sagewort	Per	Nat	h	2	1	05	05	2	1	1										2										3							9	1
HEGR	Gooseberry leaved Alumroot	Per	Nat	h			05	05				05										05						05					05		1	1		8	1
ARDR	Green sagewort, wild tarragon	Per	Nat	h	2	05	05	1	1	05				05		05					1						1				2			05				12	1
CHVI	Hairy Golden Aster	Per	Nat	h	05	1	05	05	1	1	1	05	05	05	05					05	05			05				05		05	2							17	1
CAHI	Harsh paintbrush	Per	Nat	h		05		05	05					05	05		05						05	05			1	05			1								11	1
HECY	Hound's Tongue Hawkweed	Per	Nat	h			05	1				05		05	05		05	05	05	05				05		05				05								12	1
AGIN	Interrupted Bentgrass	Ann	Nat	g		1						1	05	2	1			2		1	1	05	1	05	05	1	05		05	05	05		05	05				19	1
SIAL	Jim Hill Mustard	Ann	Weed	h		05			05						05	05		05	05																			6	1
KOCR	June Grass	Per	Nat	g	05			05	1	05	05		1		05		1	2		05																		10	1
POPR	Kentucky Bluegrass	Per	Intro	g		1									3			1	05	3		2																6	1
Mesb	Leafy bluebells	Per	Nat	h		05	05	05				05		05	05	1						05																	8	1
DEBI	Low Larkspur	Per	Nat	h	05	05	05	05	05	05	05			05	05	05		05						05															12	1
SOMI	Missouri Goldenrod	Per	Nat	h	1	1	05	1		05	05	1	05	05	05		1		1	1	05	05	1	1	05	1	05	05		2	1	1	1			1	05	27	1
DEPI	Mountain Tansy Mustard	Ann	Weed	h	05	05											05	05	05	05			05				05										05	9	1
Lote	Nine leaf lomatium	Per	Nat	h		05		05		05				05	05	05	05			05	05						05											10	1
PYMA	Ninebark	Per	Nat	s	2			05												2		2			3	2	1	05		1	1	05	2	2	2	4	1	16	1
ACCE	Nodding Onion	Per	Nat	h		05	05	05	05			05			05	05	05		05	05	05	05		1	05	1	05	05		05							05	18	1
BERE	Oregon Grape	Per	Nat	s															1			05			1		1		05	2							6	1
ALAL	Pale alyssum	Ann	Weed	h	2	3	05	1	2	1	2	1	1	2	1	2	05	1		1	05		1	3		05	1		05	2	05		1					24	1
ANMA	Pearly Everlasting	Per	Nat	h																	05			05	05	05	05			05				05				7	1
CARU	Phegrass	Per	Nat	g		05									1			1			1		3			1	1					05		1	3	4	11	1
MIOR	Pink Microseris	Ann	Nat	h				05						05							05			05			05	05		05	05							9	1
PIPO	Ponderosa Pine, Western Yellowpine, Bull Pine	Per	Nat	t	1			05		1		2	05		3		05		1	2	2	2	2	1	2	2	2	2		1		2		1	3	2	22	1
JUSC	Rocky Mountain Juniper	Per	Nat	t	4	1			1	1	1	1			1					1	1	2		05	05	2	2	05		3	1			05		1		19	1
ANMI	Rosy Pussytoes	Per	Nat	h	05	05	1	2	05	05		1			05		1		1	05	05	05	1				05			1					05	05	18	1
FESC	Rough Fescue	Per	Nat	g	1		2	2				2		1							05	1	2	2		1	05	05		05	1			05		1		10	1
PHLI	Sand Phacelia	Ann	Nat	h	05	05			1						05	05		1	1		05	05	05	05			05	05		05	05							15	1
AMAL	Serviceberry, Saskatoon	Per	Nat	s						05							05							1	2		1	1	1	05	1			05	05	1	1	14	1
ERPU	Shaggy Fleabane	Per	Nat	h	1	05			05	05		05	05	05													05											8	1
PHHA	Silverleaf Phacelia	Per	Nat	h	05				05					1		05				05		05		05	05	05		05						05	05	05	05	05	15	1
LUAR	Silvery Lupine	Per	Nat	h										2	1	1	05	1	05	05	1			1	1		1	05			05							14	1
MYMI	Slender Forget-me-not	Ann	Intro	h	1		1		05	05	1		05	05			05	05							05		05				1							12	1
LIPA	Small flowered Fringecup	Per	Nat	h	05	05	05			05			05	05	05	05	05	05	05	1		05	05	05			05											18	1
CEMA	Spotted Knapweed	Per	Nmo	h	1	2	1	1	05	05	05	1		05	05	05			1	05			1				1	05	05	05		1			05	05	18	1
ERDI	Spreading Fleabane	Per	Nat	h	05			05	05						05	05														05								6	1
POGL	Sticky Cinquefoil	Per	Nat	h		05	05	05			05	1			1		05	05	05	05		05			05					05								13	1
ERUM	Sulphur Buckwheat	Per	Nat	h		05	1	1		05		05			05																							6	1
EPPA	Tall Annual Willow Herb	Ann	Weed	h	05		05	05				1	05	05	05	05	05		1		05		05	1			05	1		05	1							17	1
ORTE	Twin-leaved Owl Clover	Ann	Nat	h	1	1	3	3				2		05	1	2	1	1	05	1		05	05											05				15	1
STAM	Twisted Stalk	Per	Nat	h																05		05																8	1
RICE	Wax or Squaw Currant	Per	Nat	s											05		1		1		1	1															1	9	1
LIRU	Wayside Gromwell, Puccoon	Per	Intro	h	05	05	05	1	05	05				05	05	1	05	05	05	1	05		05	1	05	05	1	05	1		1		05	05			05	05	28	1
ASMI	Weedy Milkvetch	Per	Nat	h	05	1			05												05		05		2													6	1
LARE	Western Stickseed	Ann	Nat	h	05	1	05	1	05	1		05	05	05		05		05	05	05	05	05	05	1	05	05	1	1	05	1	05				05				25	1
BRCO	Wild Hyacinth	Per	Nat	b			05	05						05		05					1	05	05	05														9	1
ROWO	Wood's Rose	Per	Nat	s	05		05					05														05			2				05	1		05		9	1
FRVE	Woods strawberry	Per	Nat	h			05					05								05					05	1		05				05	05		1	1	05	11	1
LOAM	Wyeth's or Desert swale biscuit root	Per	Nat	h		05	05	05	05	05				05							05			05	05		05											10	1
CALI	Wyoming Paintbrush	Per	Nat	h		05	05			05										05							05			05								8	1
PEGA	Yampah	Per	Nat	h			05	05				2										05				1											05	6	1
ACMI	Yarrow, Milfoil	Per	Nat	h	1	1	1	05	2	05	05	05	05	05	1	05	05		1	05	05	05	1	1	1	05	1			1	1	05			05		27	1
TRDU	Yellow salsify, (Goatsbeard)	Bien	Intro	h	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05		05	05			05	05		05	05							23	1
Aspect					180	240	270	270	180	135	115	285	180	150	200	285	240	220	180	135	180	230	150	180	270	190	170	180	180	215	150	185	170	180	220	265	270		
Elevation					4900	5100	5100	5260	5050	5200	5250	5360	5400	5580	5440	5720	5000	5620	5740	5360	5080	5290	5480	5680	5290	5060	5440	5620	5400	5240	4840	4840	4960	5060	5100	5240	5380		
Slope					45	35	23	21	28	20	33	22	25	24	10	20	17	25	25	0	28	20	25	27	27	10	25	25	60	24	35	30	35	50	35	15	27		
					P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33		
					SAV	SAV	SAV	SAV	SAV	SAV	SAV	SAV	SAV	GRS	SAV	GRS	SAV	GRS	SAV	ECO	SAV	OFT	SAV	OFT	OFT	OFT	SAV	SAV	SCR	SAV	SAV	ECO	ECO	ECO	ECO	OFT	OFT		

Appendix D: Composition summary of vegetation data in Sawmill Creek RNA

					Mixed Savannah						Savannah Shrub			Grassland							Forest				Riparian			
Plot #	P1	P11	P16	P13	P15	P17	P23	P19	P20	P24	P28	P3	P4	P9	P2	P8	P6	P5	P7	P27	P10	P12	P14	P18	P33	P32	P21	P22	P25	P35	P26	P29	P31
# Species	50	43	45	38	41	36	46	40	40	43	47	52	47	46	49	40	40	27	29	34	45	36	33	42	28	22	35	38	8	41	49	56	54
Diversity	3.69	3.49	3.66	3.45	3.54	3.43	3.62	3.55	3.47	3.59	3.85	3.74	3.64	3.68	3.68	3.50	3.49	3.05	3.13	3.34	3.51	3.33	3.28	3.54	3.08	2.76	3.33	3.47	2.14	3.57	3.78	3.85	3.84
Evenness	0.944	0.928	0.944	0.936	0.953	0.956	0.948	0.961	0.94	0.955	0.949	0.947	0.946	0.951	0.945	0.948	0.947	0.925	0.94	0.946	0.927	0.929	0.932	0.946	0.924	0.893	0.938	0.955	0.973	0.953	0.946	0.957	0.951
Growth annual	11	8	9	8	11	8	11	13	11	8	11	8	8	7	10	11	7	10	5	9	13	11	12	7	3	1	8	5	4	8	2	4	1
Growth Bien	3	1	2	1	2	1	2	2	2	1	4	2	2	3	1	2	2	2	2	2	2	2	2	0	0	1	0	0	1	2	2	4	4
Growth Peren	36	34	35	31	29	27	33	25	27	36	32	42	37	36	39	27	31	15	21	23	30	23	19	35	25	20	29	33	4	32	45	48	49
% annual species	22.0	18.6	19.6	15.8	26.8	22.2	23.9	32.5	27.5	14.0	23.4	15.4	17.0	15.2	20.4	27.5	17.5	37.0	17.9	26.5	29.9	30.6	36.4	18.7	10.7	4.5	17.1	13.2	44.4	14.6	4.1	7.1	1.9
Origin Introduced	3	4	3	3	4	2	4	4	5	3	3	5	4	4	4	5	6	5	3	3	5	4	5	3	2	1	2	1	1	1	1	1	1
Origin Natural	40	31	40	34	31	32	37	31	32	39	38	44	39	39	38	31	31	19	22	29	38	29	24	39	25	21	33	35	5	35	48	50	51
Origin Noxious weeds	2	1	1	0	1	0	1	1	0	1	1	1	1	1	2	1	1	0	?	0	1	1	0	0	0	0	0	0	1	0	0	1	0
Origin Weed	5	4	4	3	5	2	4	4	3	1	5	2	3	2	5	3	2	3	1	3	2	3	4	0	1	0	0	2	3	1	2	4	2
% weeds of total	14.0	11.6	10.9	7.9	14.6	5.6	10.9	12.5	7.5	4.7	12.8	5.8	8.5	8.5	14.3	10.0	7.5	11.1	10.7	8.8	6.7	11.1	12.1	0.0	3.6	0.0	0.0	5.3	33.3	9.8	4.1	8.9	3.7
Family Total	22	19	19	14	21	17	19	20	19	22	20	19	20	20	20	14	16	13	15	17	21	19	18	21	15	14	20	20	7	23	24	27	26
# sp Boraginace	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
# sp Caryophyll	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
# species Composite	12	8	9	5	8	8	8	8	7	5	10	14	13	12	11	9	9	4	6	8	7	4	0	8	6	3	3	7	0	7	7	10	5
# species Cruciferae	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0	5	3	3	0	0	0	3	5	0	0	0	0	3	0	0	0	4	3
# species Gramineae	5	7	7	4	5	6	6	6	5	5	5	7	8	5	7	8	9	7	4	5	7	8	6	8	4	0	4	7	0	7	7	6	7
# species Leguminose	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
# species Labiatae	3	3	5	3	3	0	3	0	3	3	3	3	3	3	3	3	0	0	0	0	0	3	0	3	0	0	4	3	0	0	0	0	3
# species Ranunculac	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
# species Rosaceae	3	0	0	4	0	0	3	0	0	4	3	0	0	4	0	0	0	0	0	0	0	0	0	3	3	4	4	0	0	4	7	5	3
# species Scrophulari	3	4	3	0	0	3	0	4	5	4	5	4	4	0	4	3	3	0	3	4	4	0	0	0	0	0	3	0	0	0	0	3	3
# species Umbelliferae	0	0	0	4	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
	30	22	30	26	14	17	26	16	20	21	29	28	26	24	31	29	24	14	13	18	22	16	11	20	13	7	18	29	0	18	21	28	30
%variation of total	69	51.1628	65.2174	69.4211	34.1463	47.2222	56.5217	40	50	49.8372	61.7021	53.8462	55.3191	52.1739	63.2653	72.5	69	51.0519	49.4286	52.9412	48.8889	44.4444	33.3333	47.619	49.4286	31.8182	51.4286	52.8318	0	43.9024	42.85714	50	55.5556
Slope	45	10	0	17	25	28	25	25	27	25	24	23	21	22	35	28	20	25	33	35	24	20	25	20	22	15	27	10	60	50	30	35	35
Aspect	180	200	135	240	180	180	170	150	180	180	215	220	220	265	240	180	135	180	115	160	150	295	220	230	270	265	270	190	180	180	195	170	220
Elevation	4800	5440	5360	6000	5740	5040	5440	5480	5690	5820	5740	5100	5260	5360	5100	5050	5200	5410	5250	4940	5560	5720	5820	5290	5390	5240	5290	5060	5470	5060	4940	4960	5100
Field Class	SAV	SAV	ECO	SAV	SAV	SAV	SAV	SAV	OFT	SAV	SAV	SAV	SAV	SAV	SAV	SAV	SAV	SAV	SAV	SAV	ORS	ORS	ORS	OFT	OFT	CFT	OFT	OFT	SCR	ECO	ECO	ECO	ECO
Cluster Class	Mix Sav	Mix Sav	Mix Sav	Mix Sav	Mix Sav	Mix Sav	Mix Sav	Mix Sav	Mix Sav	Mix Sav	Mix Sav	Shr Sav	Shr Sav	Shr Sav	Grs	Grs	Grs	Grs	Grs	Grs	Grs	Grs	Grs	Oft	Oft	Oft	Oft	Oft	EPar	EPar	EPar	EPar	EPar

Appendix E: Tree core and age data from study plots

Habitat	Plot #	Tag #	Core #	Species	DBH-cm	Vigor Cl.	Age	10 yr inc.-mm
Eco/Rip	28		1	df	62.2		132	20
Eco/Rip	29	81	1	df	54.1		133	11
Eco/Rip	31	112	1	df	70.6		147	8
Eco/Rip	29	81	2	pp	76.5	1C	182	9
Eco/Rip	31	112	2	pp	94.7	2C	200	5
Grs	7	304	1	df	42.7			20
Grs	6	111	1	pp	59.7	1A	75	14
Grs	9	486	1	pp	69.9	1B	110	15
Oft	33	353	1	df	20.4		78	9
Oft	18	336	1	df	52.4		100	10
Oft	32	379	2	df	45.9		118	10
Oft	21	303	1	df	46.1		156	7
Oft	22	105	1	df	73.2		195	8
Oft	22	105	3	pp	29.8	1B	118	10
Oft	18	336	2	pp	62.1	3C	218	
Oft	18	336	3	pp	71.1	DEAD	275	3
Oft	32	379	1	pp	85.2	4D	275	3?
Oft	21	303	3	pp	48.3			7
Oft	22	105	2	pp	59.6	1A		10
Oft	21	303	2	pp	76.1	1A		6
Sav/mix	16	16	1	df	25		56	9
Sav/mix	19	744	1	df	42.4		83	28
Sav/mix	20	258	1	df	43.8		87	26
Sav/mix	13	746	1	df	71		106	25
Sav/mix	24	704	2	df	52			14
Sav/mix	23	965	3	JS	17.6			14
Sav/mix	26	90	1	pp	25	2C	52	20
Sav/mix	20	258	2	pp	22.6	1A	53	24
Sav/mix	19	744	2	pp	28.8	1A	74	8
Sav/mix	23	965	2	pp	27.2	1C	75	20
Sav/mix	16	16	2	pp	59.7	1A	103	8
Sav/mix	17	384	1	pp	51.3	1A	121	13
Sav/mix	11	229	1	pp	72.4	2A	127	12
Sav/mix	15	33	1	pp	71	1A	132	12
Sav/mix	17	384	2	pp	66.9	1B	134	5
Sav/mix	13	746	2	pp	55	1A	142	7
Sav/mix	23	965	1	pp	54.2	2A	149	10
Sav/mix	24	704	1	pp	49.6	4B	158	8
Sav/Shr	8	10	2	df	14.5		23	38
Sav/Shr	8	10	1	pp	17.2	1A	18	35
Sav/Shr	4	179	1	pp	10.5	1D	20	20

Appendix F: Tree structure data from study plots

Plot #	Species	Dbh cm	Canopy Class	Height (m)	Vigor Class	Habitat
1	PP	7.5	C	3	1A	Sav
1	PP	11.0	C	4.5	1B	Sav
4	PP	10.5	D		1D	Sav
6	PP	48.4		51.96	2A	Sav
6	PP	59.7		53.69	3A	Sav
8	PP	7.6		5.6	1D	Sav
8	PP	8.7		7.64	1A	Sav
8	PP	10.0		26.59	1A	Sav
8	PP	13.1		11.2	1A	Sav
8	PP	17.2		12.5	1A	Sav
8	PP	21.7		17.51	1A	Sav
9	PP	69.6		53.31	2A	Sav
11	PP	51.7		52.2	2B	Sav
11	PP	57.8		50.1	2A	Sav
11	PP	65.6		40.3	2B	Sav
11	PP	69.2		32.77	2B	Sav
11	PP	72.4		46.33	2A	Sav
13	PP	50.0		45.4	2B	Sav
13	PP	55.0		45.4	2A	Sav
15	PP	7.2		4	1A	Sav
15	PP	71.0		54.97	2A	Sav
16	PP	25.9	C		2A	Eco/Sav
16	PP	28.5	C		2C	Eco/Sav
16	PP	59.2	C	66.57	2B	Eco/Sav
16	PP	59.2	C	65.82	2C	Eco/Sav
17	PP	13.8	D	6.45	1D	Sav
17	PP	20.5	D	13.12	2D	Sav
17	PP	39.1	D	115.11	2C	Sav
17	PP	42.1	D	55.55	2B	Sav
17	PP	45.5	D	36.88	2A	Sav
17	PP	51.3	D	47.32	2A	Sav
17	PP	63.0	D	89.82	2A	Sav
17	PP	66.9	D		2B	Sav
18	PP	5.1			1C	Oft
18	PP	5.5			1D	Oft
18	PP	6.6			1C	Oft
18	PP	7.0			1D	Oft
18	PP	9.5			1C	Oft
18	PP	10.1			1B	Oft
18	PP	11.2			1D	Oft
18	PP	11.3			1C	Oft
18	PP	11.4			1D	Oft
18	PP	11.6			1C	Oft
18	PP	12.0			1C	Oft
18	PP	12.1			1D	Oft
18	PP	15.7			1C	Oft
18	PP	15.8			1C	Oft
18	PP	16.5			1D	Oft
18	PP	20.4			2D	Oft
18	PP	21.0			2C	Oft
18	PP	23.5			2C	Oft
18	PP	23.5			2D	Oft
18	PP	28.0			2C	Oft
18	PP	62.1	C		3C	Oft
18	PP	81.3	C	106.48	3D	Oft
19	PP	5.0			1A	Sav
19	PP	6.7			1D	Sav
19	PP	6.7			1A	Sav
19	PP	7.0			1A	Sav
19	PP	7.4		4	1D	Sav
19	PP	7.7			1A	Sav
19	PP	8.4			1A	Sav
19	PP	8.5			1A	Sav
19	PP	9.4			1A	Sav
19	PP	9.4			1A	Sav
19	PP	9.7			1A	Sav
19	PP	9.8			1A	Sav
19	PP	10.8			1A	Sav
19	PP	15.3	I	13.91	1A	Sav
19	PP	16.1	I		1A	Sav
19	PP	23.0	I		1A	Sav
19	PP	24.3	I		2A	Sav
19	PP	28.8	D	30.83	2A	Sav
19	PP	29.7	D		2B	Sav
20	PP	22.6		14.48	1A	Dft
21	PP	22.0			2D	Oft
21	PP	23.5	C		2B	Oft
21	PP	25.3	C		2B	Oft
21	PP	26.3	C		2B	Oft
21	PP	28.1	C		2B	Oft
21	PP	29.5	C		2B	Oft
21	PP	31.3	C		2B	Oft
21	PP	32.7	C		2B	Oft
21	PP	35.0	C		2B	Oft
21	PP	36.1	C		2B	Oft
21	PP	36.4	C		2B	Oft
21	PP	48.3	C		2B	Oft
21	PP	76.1		45.12	3A	Oft
21	PP	85.1	C		3C	Oft
22	PP	19.1	I		1D	Oft
22	PP	27.1	C		2C	Oft
22	PP	29.9	C		2B	Oft

22	PP	36.9	C		2D	Oft
22	PP	52.6	C		2B	Oft
22	PP	59.6	C	26.35	3A	Oft
23	PP	5.1	S		1A	Sav
23	PP	10.2	S		1D	Sav
23	PP	11.3	S	9.35	1D	Sav
23	PP	27.2	I	25.29	2C	Sav
23	PP	29.7			2C	Sav
23	PP	54.2	D	43.46	2A	Sav
24	PP	31.6	I		2D	Sav
24	PP	41.8	C	64.15	2A	Sav
24	PP	49.6	C	42.16	2B	Sav
24	PP	52.4	C	60.59	2C	Sav
26	PP	5.5	S		1D	Sav
26	PP	25.0	I	17.46	2C	Sav
29	PP	6.2	S		1D	Eco/Rip
29	PP	16.5	I		1D	Eco/Rip
29	PP	76.5	D	96.59	3C	Eco/Rip
31	PP	94.7	D	97.85	3C	Eco/Rip
32	PP	7.0	S		1D	Cft
32	PP	13.3			1C	Cft
32	PP	18.4			1D	Cft
32	PP	85.2	C	51.33	3D	Cft
33	PP	8.0			1C	Oft
33	PP	9.0			1D	Oft
33	PP	10.5			1C	Oft
33	PP	25.1			2C	Oft
33	PP	26.8			2C	Oft
33	PP	83.1			3D	Oft
33	PP	87.3	D	73.01	3D	Oft
1	JS	10.0	C	5		Sav
1	JS	11.0	C	5		Sav
1	JS	12.5	C	5		Sav
1	JS	25.5	C	6		Sav
2	JS	7.5				Sav
2	JS	7.8				Sav
5	JS	7.0				Sav
5	JS	8.5				Sav
5	JS	10.6				Sav
6	JS	9.1				Sav
6	JS	13.8				Sav
16	JS	9.9	S			Eco/Sav
16	JS	13.5	S			Eco/Sav
17	JS	13.0	S	5		Sav
17	JS	23.5	S	4		Sav
18	JS	7.7				Oft
22	JS	5.2	S			Oft
22	JS	11.9	S	7		Oft
22	JS	12.2	S	7		Oft
23	JS	13.0	S	5		Sav
23	JS	17.0	S	4		Sav
23	JS	17.6	S	8		Sav
26	JS	7.2	S			Sav
26	JS	7.5	S	5		Sav
26	JS	7.7	S	4		Sav
26	JS	9.0	S	5		Sav
26	JS	9.8	S	6		Sav
26	JS	10.2	2	7		Sav
26	JS	10.5	S			Sav
26	JS	11.2	S	7.5		Sav
7	DF	42.7		19.53		Sav
8	DF	8.3		10.5		Sav
8	DF	8.5		10.5		Sav
8	DF	14.5		15.94		Sav
13	DF	71.0		48.13		Sav
16	DF	5.2	C			Eco/Sav
16	DF	5.2	C			Eco/Sav
16	DF	5.9	C			Eco/Sav
16	DF	5.9	C			Eco/Sav
16	DF	6.6	C			Eco/Sav
16	DF	6.7	C			Eco/Sav
16	DF	6.8	C			Eco/Sav
16	DF	7.0	C			Eco/Sav
16	DF	7.5	C			Eco/Sav
16	DF	8.1	C			Eco/Sav
16	DF	8.1	C			Eco/Sav
16	DF	8.1	C			Eco/Sav
16	DF	8.1	C			Eco/Sav
16	DF	8.4	C			Eco/Sav
16	DF	8.4	C			Eco/Sav
16	DF	8.5	C			Eco/Sav
16	DF	8.6	C			Eco/Sav
16	DF	8.9	C			Eco/Sav
16	DF	9.2	C			Eco/Sav
16	DF	9.4	C			Eco/Sav
16	DF	9.5	C			Eco/Sav
16	DF	9.7	C			Eco/Sav
16	DF	9.8	C			Eco/Sav
16	DF	9.9	C			Eco/Sav
16	DF	10.1	C			Eco/Sav
16	DF	10.5	C			Eco/Sav
16	DF	10.5	C			Eco/Sav
16	DF	10.6	C			Eco/Sav

16	DF	10.8	C			Eco/Sav
16	DF	11.3	C			Eco/Sav
16	DF	11.4	C			Eco/Sav
16	DF	11.5	C			Eco/Sav
16	DF	11.5	C			Eco/Sav
16	DF	11.5	C			Eco/Sav
16	DF	11.5	C			Eco/Sav
16	DF	11.8	C			Eco/Sav
16	DF	11.8	C			Eco/Sav
16	DF	12.0	C			Eco/Sav
16	DF	12.0	C			Eco/Sav
16	DF	12.1	C			Eco/Sav
16	DF	12.1	C			Eco/Sav
16	DF	12.2	C			Eco/Sav
16	DF	12.3	C			Eco/Sav
16	DF	12.4	C			Eco/Sav
16	DF	12.5	C			Eco/Sav
16	DF	12.7	C			Eco/Sav
16	DF	13.0	C			Eco/Sav
16	DF	13.1	C			Eco/Sav
16	DF	13.1	C			Eco/Sav
16	DF	13.5	C			Eco/Sav
16	DF	13.6	C			Eco/Sav
16	DF	13.7	C			Eco/Sav
16	DF	13.7	C			Eco/Sav
16	DF	13.8	C			Eco/Sav
16	DF	13.9	C			Eco/Sav
16	DF	14.2	C			Eco/Sav
16	DF	14.4	C			Eco/Sav
16	DF	14.8	C			Eco/Sav
16	DF	14.8	C			Eco/Sav
16	DF	14.9	C			Eco/Sav
16	DF	15.1	C			Eco/Sav
16	DF	15.5	C			Eco/Sav
16	DF	15.8	C			Eco/Sav
16	DF	16.0	C			Eco/Sav
16	DF	16.2	C			Eco/Sav
16	DF	16.5	C			Eco/Sav
16	DF	16.8	C			Eco/Sav
16	DF	16.8	C			Eco/Sav
16	DF	16.8	C			Eco/Sav
16	DF	16.9	C			Eco/Sav
16	DF	17.0	C			Eco/Sav
16	DF	17.0	C			Eco/Sav
16	DF	17.2	C			Eco/Sav
16	DF	17.2	C			Eco/Sav
16	DF	17.5	C			Eco/Sav
16	DF	17.6	C			Eco/Sav
16	DF	17.7	C			Eco/Sav
16	DF	17.7	C			Eco/Sav
16	DF	17.9	C			Eco/Sav
16	DF	18.7	C			Eco/Sav
16	DF	19.1	C			Eco/Sav
16	DF	19.7	C			Eco/Sav
16	DF	20.0	C			Eco/Sav
16	DF	20.7	C			Eco/Sav
16	DF	20.9	C			Eco/Sav
16	DF	21.0	C			Eco/Sav
16	DF	21.5	C			Eco/Sav
16	DF	22.8	C			Eco/Sav
16	DF	24.8	C	30.33		Eco/Sav
16	DF	25.0	C	22.87		Eco/Sav
16	DF	25.8	C			Eco/Sav
16	DF	27.0	C			Eco/Sav
18	DF	5.2				Oft
18	DF	7.8				Oft
18	DF	7.8				Oft
18	DF	8.3				Oft
18	DF	8.7				Oft
18	DF	8.9				Oft
18	DF	9.5				Oft
18	DF	10.8				Oft
18	DF	11.3				Oft
18	DF	11.5				Oft
18	DF	12.3				Oft
18	DF	13.4				Oft
18	DF	13.8				Oft
18	DF	14.1				Oft
18	DF	14.3				Oft
18	DF	15.3				Oft
18	DF	16.1				Oft
18	DF	16.7				Oft
18	DF	17.7				Oft
18	DF	17.8				Oft
18	DF	18.2				Oft
18	DF	19.0				Oft
18	DF	19.0				Oft
18	DF	20.8				Oft
18	DF	21.0				Oft
18	DF	23.5				Oft
18	DF	24.0				Oft
18	DF	24.2		32.05		Oft
18	DF	25.7				Oft

Appendix F: Tree structure data from study plots

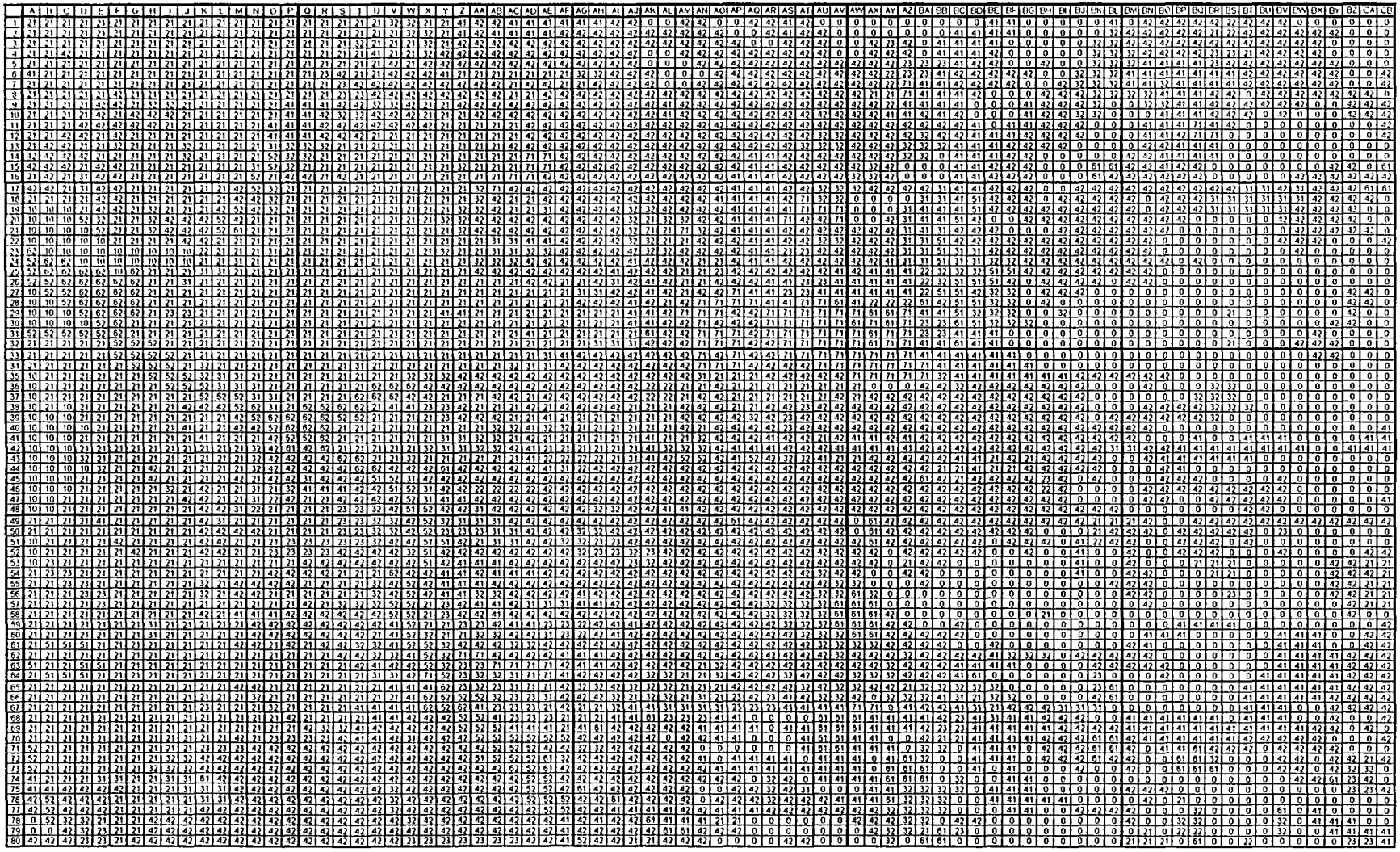
18	DF	27.4				Oft
18	DF	27.6				Oft
18	DF	28.6	C			Oft
18	DF	29.2				Oft
18	DF	31.3	D			Oft
18	DF	32.4	D			Oft
18	DF	34.2	D			Oft
18	DF	34.7	C			Oft
18	DF	45.2	D			Oft
18	DF	52.4	D	55.81		Oft
19	DF	6.1				Sav
19	DF	6.2				Sav
19	DF	9.2				Sav
19	DF	42.4	D	33.42		Sav
20	DF	43.8		32.48		Oft
21	DF	5.6				Oft
21	DF	8.6				Oft
21	DF	9.2				Oft
21	DF	10.0				Oft
21	DF	11.6				Oft
21	DF	23.4	C			Oft
21	DF	32.5	C			Oft
21	DF	33.8	C			Oft
21	DF	36.1	C			Oft
21	DF	44.0	C			Oft
21	DF	45.5	C			Oft
21	DF	46.1		16.18		Oft
22	DF	11.1	I			Oft
22	DF	24.3	I			Oft
22	DF	25.0	I			Oft
22	DF	26.4	I			Oft
22	DF	29.2	C			Oft
22	DF	30.8	C			Oft
22	DF	34.8	C			Oft
22	DF	39.2	C			Oft
22	DF	41.1	C			Oft
22	DF	59.0	C			Oft
22	DF	73.2	C	19.52		Oft
24	DF	52.0	C	45.34		Sav
26	DF	5.7	S			Sav
26	DF	6.5	S			Sav
26	DF	7.2	S			Sav
26	DF	7.7	S			Sav
26	DF	8.0	S			Sav
26	DF	8.9	S			Sav
28	DF	62.2	D	65.63		Eco/Rip
28	DF	66.3	D	75.92		Eco/Rip
29	DF	6.2	S			Eco/Rip
29	DF	7.1	S			Eco/Rip
29	DF	9.0	S			Eco/Rip
29	DF	10.8	S			Eco/Rip
29	DF	17.4	I			Eco/Rip
29	DF	17.5	S			Eco/Rip
29	DF	18.0	I			Eco/Rip
29	DF	23.2	I			Eco/Rip
29	DF	24.4	I			Eco/Rip
29	DF	30.6	I			Eco/Rip
29	DF	30.9	I			Eco/Rip
29	DF	36.1	I			Eco/Rip
29	DF	37.4	I			Eco/Rip
29	DF	37.4	I			Eco/Rip
29	DF	37.8	I			Eco/Rip
29	DF	54.1	D	70.94		Eco/Rip
31	DF	34.4	D			Eco/Rip
31	DF	49.8	D	31.49		Eco/Rip
31	DF	54.7	D	61.18		Eco/Rip
31	DF	58.7	D			Eco/Rip
31	DF	64.0	D			Eco/Rip
31	DF	70.6	D	71.02		Eco/Rip
32	DF	5.7	S			Cft
32	DF	7.6	S			Cft
32	DF	7.8	S			Cft
32	DF	7.9				Cft
32	DF	9.6				Cft
32	DF	10.3	I			Cft
32	DF	10.7				Cft
32	DF	10.9				Cft
32	DF	12.9				Cft
32	DF	13.3				Cft
32	DF	17.1				Cft
32	DF	17.2				Cft
32	DF	17.5	I			Cft
32	DF	18.6				Cft
32	DF	19.2				Cft
32	DF	19.5	I			Cft
32	DF	21.5	I			Cft
32	DF	21.8				Cft
32	DF	23.7				Cft
32	DF	23.9				Cft
32	DF	24.0				Cft
32	DF	24.2	D			Cft
32	DF	24.7				Cft
32	DF	27.7				Cft

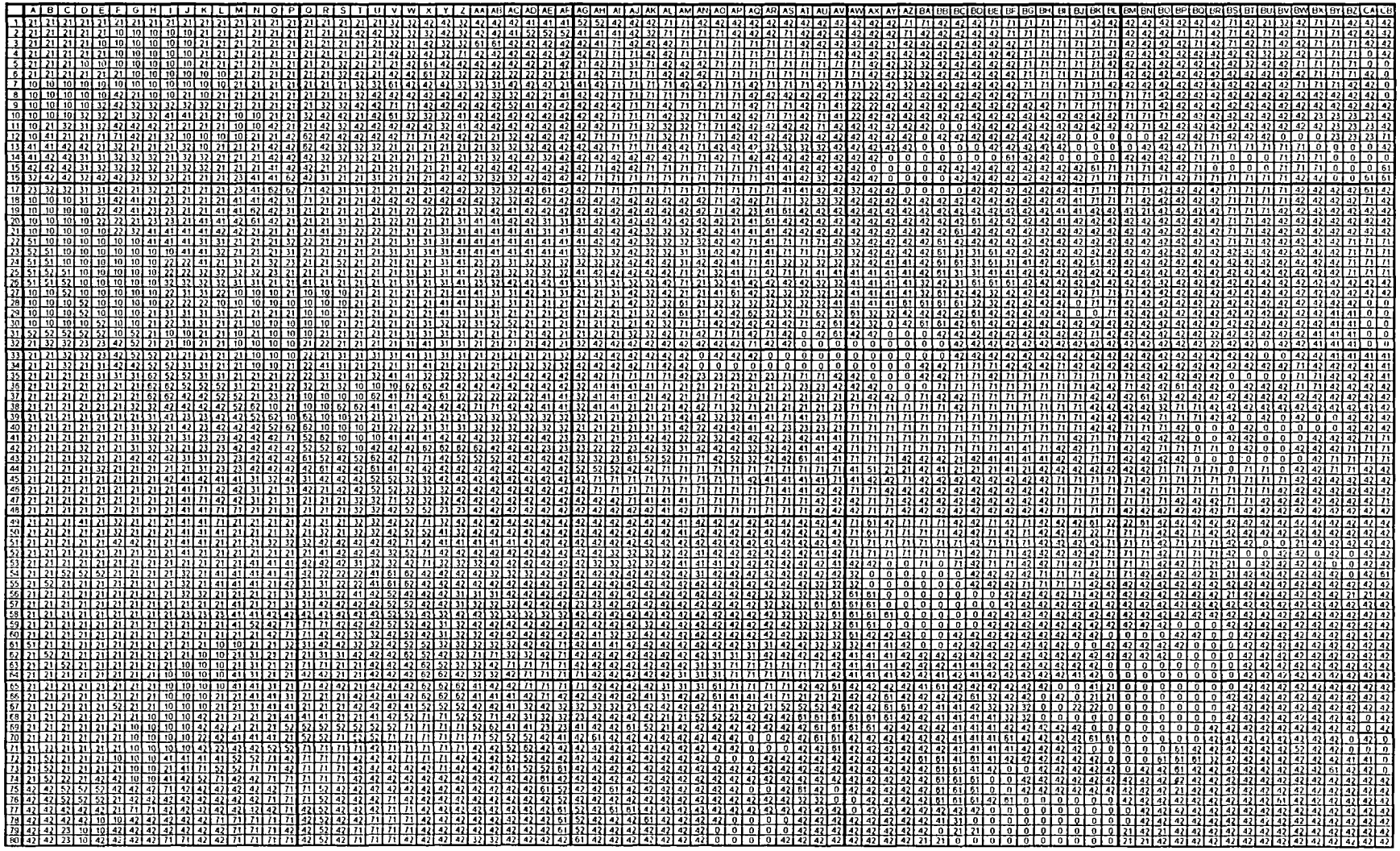
32	DF	31.0	D			Cft
32	DF	32.8	D			Cft
32	DF	34.4	D			Cft
32	DF	36.5	D			Cft
32	DF	36.7	D			Cft
32	DF	38.7	D			Cft
32	DF	39.8	D			Cft
32	DF	42.1	D			Cft
32	DF	44.3	D			Cft
32	DF	44.4	D			Cft
32	DF	45.9	C	46.53		Cft
32	DF	51.0	D			Cft
33	DF	5.5				Oft
33	DF	6.0				Oft
33	DF	6.8				Oft
33	DF	7.3				Oft
33	DF	8.4				Oft
33	DF	9.0				Oft
33	DF	10.0				Oft
33	DF	10.7				Oft
33	DF	10.9				Oft
33	DF	12.8				Oft
33	DF	13.4				Oft
33	DF	13.8				Oft
33	DF	14.2				Oft
33	DF	14.3				Oft
33	DF	14.5				Oft
33	DF	14.5				Oft
33	DF	14.8				Oft
33	DF	15.3				Oft
33	DF	16.1				Oft
33	DF	16.2				Oft
33	DF	17.6				Oft
33	DF	18.0				Oft
33	DF	18.6				Oft
33	DF	18.9				Oft
33	DF	19.8				Oft
33	DF	20.4	I	27.84		Oft
33	DF	20.8				Oft
33	DF	21.1				Oft
33	DF	21.3				Oft
33	DF	21.7				Oft
33	DF	22.6				Oft
33	DF	22.7				Oft
33	DF	24.2				Oft
33	DF	24.8				Oft
33	DF	25.8				Oft
33	DF	26.5				Oft
33	DF	26.5				Oft
33	DF	26.6				Oft
33	DF	27.0				Oft
33	DF	27.3				Oft
33	DF	27.5				Oft
33	DF	27.5				Oft
33	DF	28.0				Oft
33	DF	29.4				Oft
33	DF	30.0				Oft
33	DF	31.1				Oft
33	DF	31.7				Oft
33	DF	33.4				Oft
33	DF	37.2				Oft
22	AG	7.3	S			Oft
AG = Mountain Maple			S = Suppressed			
DF = Douglas Fir			C = Codominant			
JS = Rocky Mtn. Juniper			I = Intermediate			
PP = Ponderosa Pine			D = Dominant			
Species:			Canopy:			

Appendix G: Mapping criteria for vegetation cover types on aerial photographs

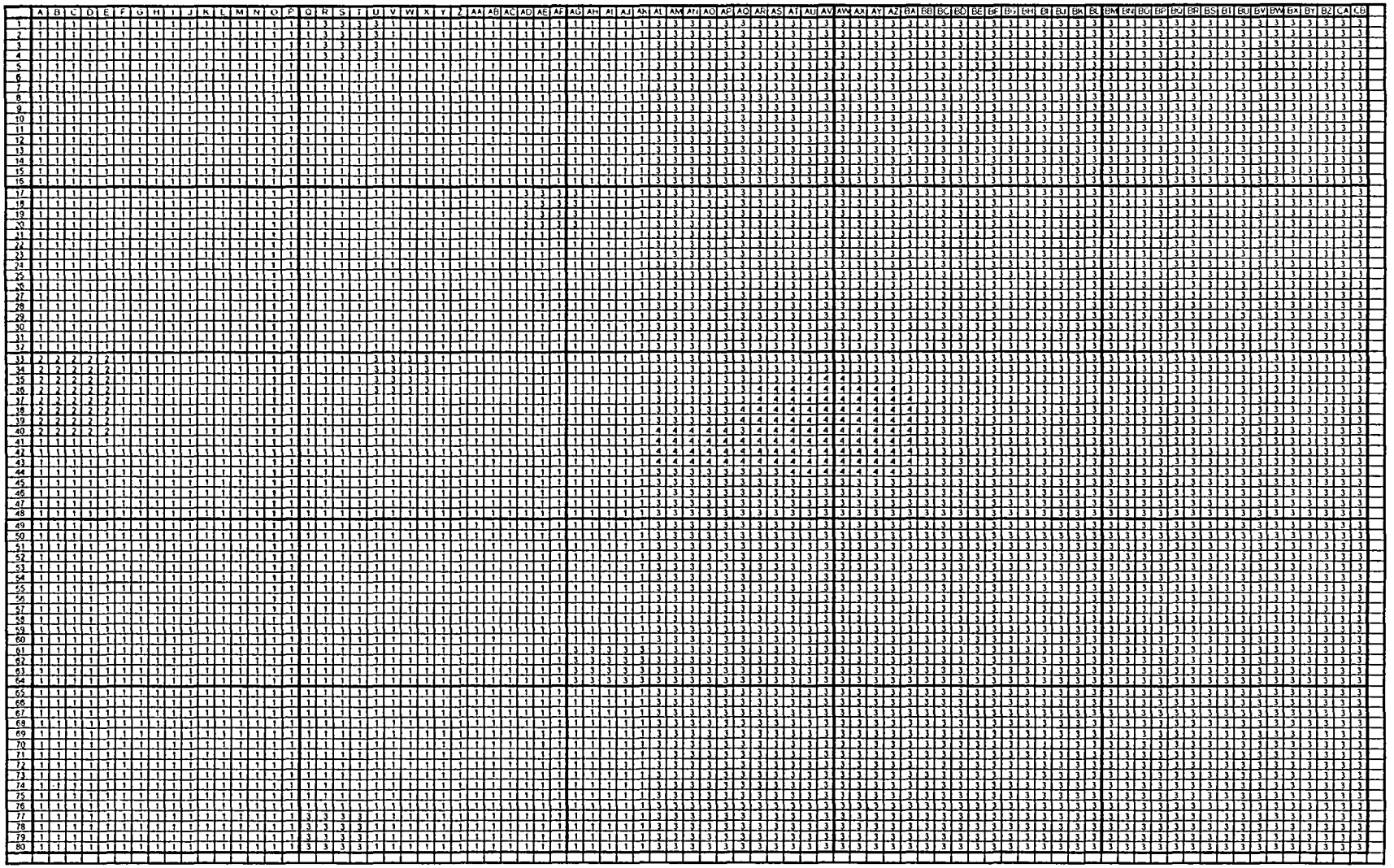
Num. Class	Classification		Date	Color	Tone	Texture	Pattern	Situation
10	**Agricultural**	**Ag**	1937	Lt. gray - dk gray matrix	Dull	Smooth	Straight-edge or curved around riparian areas. Some furrow pattern visible	Near farmsteads
			1993	green or pinkish-gray; some reddish brown	Dull	Striated on presently used fields; smooth to bumpy on older	Same as above	Same as above
21	**Grassland**	**G**	1937	White - dk gray matrix	Bright	Smooth	"Wrinkles" in drainages, few if any "dots" on surface	<10% cover by tree or shrub on rolling hilltops
			1993	lt gray or pinkish gray to greyish blue green	Dull	Smooth	Same as above	Same as above
22	**Grassland (with mainly shrubs)**	**Gs**	1937	White - Dk. gray matrix	Bright	Mostly smooth with irregularly spaced dots	Very small, < .5 mm "dots", on smooth matrix; irregular spacing	<10% cover on rolling hills or edge of drainages
			1993	light gray or pinkish gray to greyish blue green with very fine green dots	Dull to bright	Very slightly textured to smooth	Irregular patches of very fine, irregularly spaced, dl green dots, < .5 mm in diameter	Same as above
23	**Grassland (with mainly trees)**	**Gt**	1937	White - Dk. gray matrix	Bright-subdued	irregularly spaced dots	Irregular patches with irregularly spaced dots; dots >.5 mm diameter	<10% cover by trees/shrubs on rolling hilltops or drainage edge
			1993	Same as Gs but dots larger and dominantly dk. blue green	Dull-bright	Mostly smooth with irregularily spaced dots larger than Gs	Same as above	Same as above
31	**Savannah (shrub dominated)**	**Ss**	1937	White matrix with fine, black dots	Bright areas within subdued to dull	Rough	Irregular shapes & patterns within polygons; < .5 mm dots	10-25% cover on rolling hills or drainage edge
			1993	pinkish gray to blue-green with small lt. green dots	Dull-bright	Finely speckled, like a rash; rough	Same as above	Same as above
32	**Savannah (tree dominated)**	**St**	1937	White matrix, black dots	Bright areas within subdued to dull matrix	Rough	Irregular shapes & patterns within shapes; > .5 mm dots	10-25% cover on rolling hills or drainage edge
			1993	lt. grey to pinkish gray or ablue green with blue-green to black dots	Dull to bright	Rough; more coarsely speckled than Ss	Same as above	Same as above
41	**Forest (open canopy)**	**Fo**	1937	White matrix with large black dots	Mostly dark with bright areas & subdued dull shadow areas	Coarse grit, rough, bumpy	Irregularily shaped polygons and patterns within polygons	25-55% cover near drainages & on slopes, usually dry areasff
			1993	White, grey or blue-green matrix with blue green dots	Same as above	Same as above	Same as above	Same as above
42	**Forest (closed canopy)**	**Fc**	1937	Black matrix with spots of white or gray	Dark	fine grit, rough very bumpy	Mainly massive shapes & patches Some sinuous along hillside or drainages	>55% coverage, found in drainage bottoms and shaeded slopes
			1993	Dk. blue-green to black matrix with lt. green or grey openings	Dark	Fine grit, massive "bumpy"	Same as above	Same as above
100	**Forest (closed canopy, even-age)**	**Fc2**	1937	Black	Dark	Very-fine, felt-like	Irregular shapes	Within closed forest, on steep slopes
			1993	Dk. blue-green to black matrix	Dark	Very-fine, felt-like	Irregular shapes	Within closed forest, on steep slopes

51	**Riparian (forest)**	**Fr**	1937	Black matrix	Solid to spotty	Rough/bumpy	Irregular edges; sinuous or irregular	Found in drainage bottoms w/ running
							patches with large, merged dots	water (white, undulating line = stream)
			1993	Dk. blue-green matrix	Mottled with bright	Buympy; large, merged	Same as above	Same as above
				with green openings	areas	dots		
52	**Riparian (savannah)**	**Sr**	1937	White-gray matrix	Solid to spotty	Rough/bumpy	Irregular edges with small dots in	10-25% cover in drainage
				with small black dots			matrix; sinuous shapes to patches	bottoms with intermittent or
								permanent running water or upslope
								from rivers
			1993	Green to brown	Bright	Fine dots on matrix	Irregular patches of fine dots < .5 mm	Same as aboe
							in diameter	
61	**Unvegetated (talus/bare rock)**	**Ub**	1937	Light to dark gray	dull	smooth	Small, very irregular patches,	Small areas near streams or in
							variously shaped	drainages on steep inclines
			1993	Shades of blue-grey	Dull	Smooth	Same as above	Same as above
				at least present				
62	**Unvegetated (floodplain)**	**Uf**	1937	White to gray	Dull to bright	Wavy, irregular	Undulating edges of various widths	In drainage bottoms
						with light & dark		
			1993	White to light brown	Dull	Smooth with irregular	Same as above	Same as above
						white lines thread		
						through		
71	**Unvegetated (silvicult. treated??)**	**CC**	1937	Various shades of	Dull, smooth, to	Slightly bumpy,	Small to large patches of "odd" vegetation	On hillsides usually surrounded by
				gray to black	very mottles matrix	but irregular; if	compared to surround	closed or open forest; straight-edge
						dots then		boundaries present
						irregularily spaced		
				Light green patches	Solid with mottled	Very slightly textured	Same as above	Same as above
					bright areas	in irregular patches		





Appendix J: Ownership designations for grid cells in photo analsis



Appendix K: BASIC program for counting gridded ownership and cover type data grids.

```
'RNACOUNT.BAS
'Conversion of gridded data to group totals
'Maximum 15 codes, 80 columns, 80 rows
'For Pam Sikkink, Master of Science, University of Montana
'Microsoft Basic Compiler V7.0
'By Art Sikkink
DIM Code(15)
DIM Col(15)
DIM a(2, 15, 8)
'Output to CRT
'OPEN "SCRN:" FOR OUTPUT AS #3
'Output to printer
OPEN "LPT1:" FOR OUTPUT AS #3
WIDTH #3, 132
'Print 17 cpi
PRINT #3, CHR$(27) + CHR$(40) + CHR$(115) + "16.67" +
CHR$(72)
'Define Codes
Code(0) = 0
Code(1) = 10
Code(2) = 21
Code(3) = 22
Code(4) = 23
Code(5) = 31
Code(6) = 32
Code(7) = 41
Code(8) = 42
Code(9) = 51
Code(10) = 52
Code(11) = 61
Code(12) = 62
Code(13) = 71
Code(14) = 100
'Define Colors
Col(0) = 0
Col(1) = 1
Col(2) = 14
Col(3) = 3
Col(4) = 4
Col(5) = 5
Col(6) = 6
Col(7) = 7
Col(8) = 2
Col(9) = 9
Col(10) = 10
Col(11) = 11
Col(12) = 12
Col(13) = 13
Col(14) = 8
'Progam
CLS
SCREEN 7
'Define input filenames
'Input files are comma delimited Microsoft Excell exported
files.
F1$ = "1937"
F2$ = "1993"
OPEN "c:\document\rna" + F1$ + ".csv" FOR INPUT AS #1
OPEN "c:\document\rnaowner.csv" FOR INPUT AS #2
OPEN "c:\document\rna" + F2$ + ".csv" FOR INPUT AS #4
'Read and collate data
 FOR j = 0 TO 80
  FOR i = 0 TO 80
   INPUT #1, a
   INPUT #2, a2
   INPUT #4, a3
   IF i <> 0 AND j <> 0 THEN
    FOR k = 0 TO 13
     IF a = Code(k) THEN
      a(1, k, a2) = a(1, k, a2) + 1
      a(1, 15, a2) = a(1, 15, a2) + 1
      PSET (i, j), Col(k):          'Plot color
     END IF
    NEXT
    FOR k = 0 TO 13
     IF a3 = Code(k) THEN
      a(2, k, a2) = a(2, k, a2) + 1
      a(2, 15, a2) = a(2, 15, a2) + 1
      PSET (i + 100, j), Col(k):     'Plot color
     END IF
    NEXT
    FOR k = 0 TO 4
     IF a2 = k THEN
      a(0, 15, a2) = a(0, 15, a2) + 1
      PSET (i + 200, j), Col(k):     'Plot color
     END IF
    NEXT
   END IF
  NEXT
 NEXT
 FOR k = 0 TO 14
  j = 5 * k
  FOR i = 1 TO 5
   LINE (1, j + i + 100)-(10, j + i + 100), Col(k):  'Color key
  NEXT
 NEXT
'Print data code totals
 FOR k = 1 TO 2
 SELECT CASE k
  CASE 1
   PRINT #3, "Totals "; F1$
  CASE 2
   PRINT #3, "Totals "; F2$
 END SELECT
 PRINT #3, TAB(15);
 FOR i = 0 TO 14
  PRINT #3, USING "#####"; Code(i);
 NEXT
 PRINT #3,
 PRINT #3, TAB(15);
 FOR i = 0 TO 15
  PRINT #3, USING "#####"; a(k, i, 1) + a(k, i, 2) + a(k, i, 3)
+ a(k, i, 4);
 NEXT
 PRINT #3,
 PRINT #3, TAB(15);
 FOR i = 0 TO 15
  PRINT #3, USING " ###%"; (a(k, i, 1) + a(k, i, 2) + a(k, i, 3)
+ a(k, i, 4)) / 6400 * 100;
 NEXT
 PRINT #3,
 PRINT #3,
 PRINT #3, TAB(15);
 FOR i = 0 TO 15
  PRINT #3, USING "#####"; Code(i);
 NEXT
 PRINT #3,
 FOR j = 1 TO 4
  SELECT CASE j
   CASE 1
    PRINT #3, "Private       ";
   CASE 2
```

```
      PRINT #3, "Lolo NF        ";
     CASE 3
      PRINT #3, "Bitterroot NF  ";
     CASE 4
      PRINT #3, "Research Natural";
    END SELECT
    FOR i = 0 TO 15
     PRINT #3, USING "#####"; a(k, i, j);
    NEXT
    PRINT #3,
   NEXT
   PRINT #3,
   PRINT #3,
   PRINT #3, TAB(15);
   FOR i = 0 TO 14
    PRINT #3, USING "#####"; Code(i);
   NEXT
   PRINT #3,
   FOR j = 1 TO 4
    SELECT CASE j
     CASE 1
      PRINT #3, "Private       ";
     CASE 2
      PRINT #3, "Lolo NF       ";
     CASE 3
      PRINT #3, "Bitterroot NF  ";
     CASE 4
      PRINT #3, "Research Natural";
    END SELECT
    FOR i = 0 TO 14
     PRINT #3, USING "###.#"; a(k, i, j) / 6400 * 100;
    NEXT
    PRINT #3,
   NEXT
   PRINT #3, ""
   PRINT #3,
   NEXT
   PRINT #3, CHR$(12)
  CLOSE #1
  CLOSE #3
```

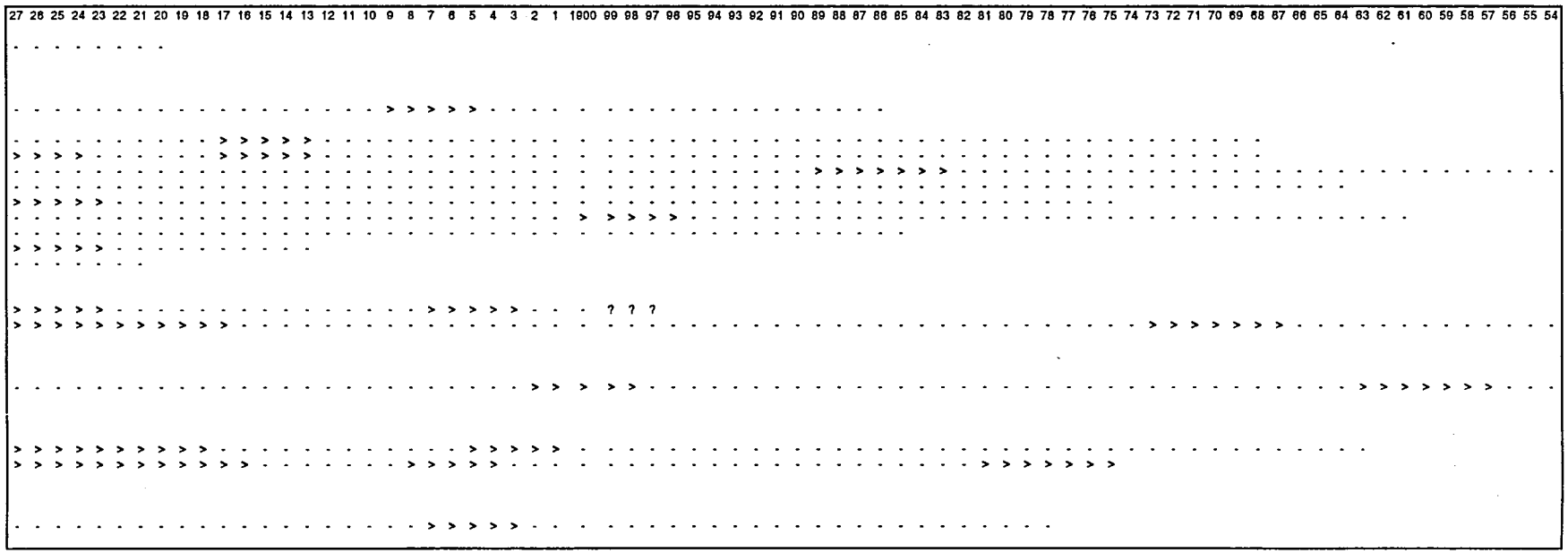
Appendix L: Tree ring Analysis

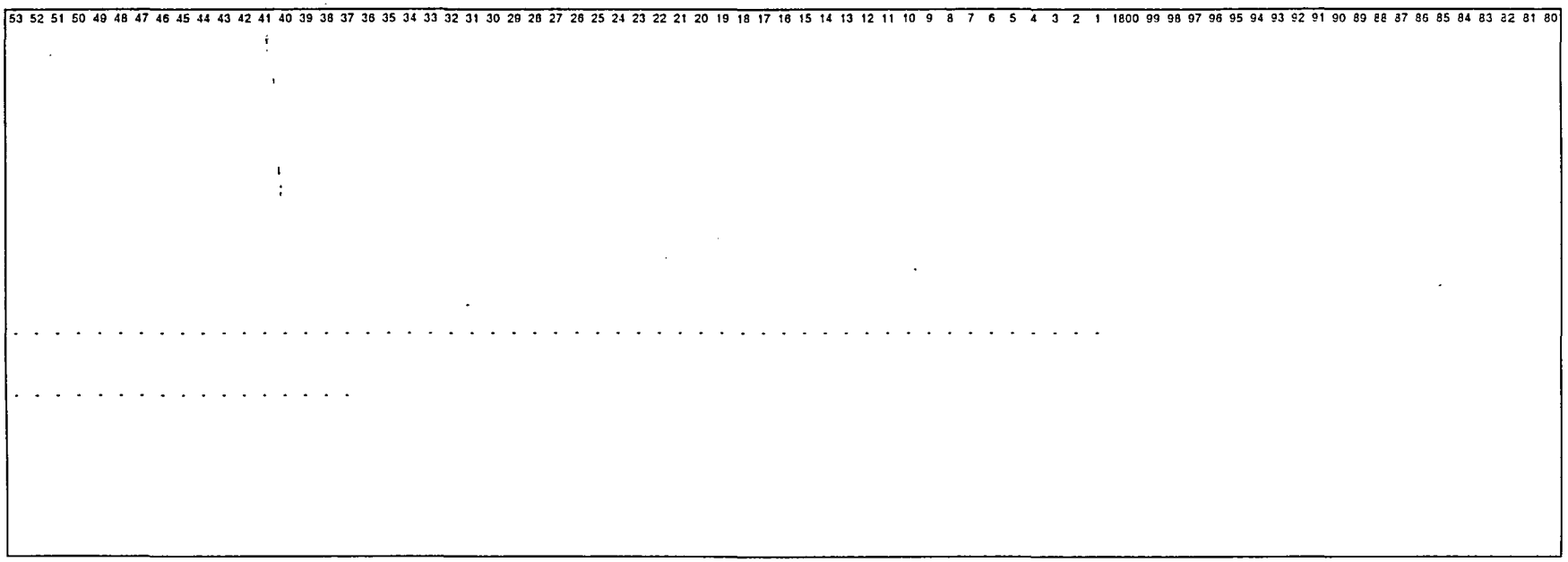
	Core		1995	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28
Shrub/Sav	4-1	pp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																																																							
Grassland	6-1	pp	>	>	>	>	>	>	>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Grassland	7-1	df	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	?	?	?	?																											
Shrub/Sav	8-1	pp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																																																													
Shrub/Sav	8-2	df	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																																																											
Grassland	9-1	pp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	-	-	-	-	-	-	-	-	-
Forest	"--"	pp																	>	>	>	>	>																																	>	>	>	>	>	>	>	>	>	>	>													
Mix/Sav	11-1	pp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	-	-
Mix/Sav	13-1	df	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	>	>
Mix/Sav	13-2	pp	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	>	>	>	>	-	-
Mix/Sav	15-1	pp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	-	-	-	-	-	-	-	-	-	-	-	-
Mix/Sav	17-1	pp	-	-	>	>	>	>	>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>
Mix/Sav	17-2	pp	>	>	>	>	>	>	>	>	>	>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	-	-	-
Forest	18-1	df	>	>	>	>	>	>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mix/Sav	19-1	df	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	>	>
Mix/Sav	19-2	pp	>	>	>	>	>	>	>	>	>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mix/Sav	20-1	df																																																																																			
Mix/Sav	20-2	pp																																																																																			
Forest	21-3	pp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>
Forest	22-1	df	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	>	>	>	>
Forest	22-3	pp																																																																																				
Mix/Sav	23-1	pp																																																																																				
Mix/Sav	23-2	pp																																																																																				
Mix/Sav	24-1	pp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	-	-	-	-	-	-	-	-	-	-	-	-
Mix/Sav	24-2	df																																																																																				
Mix/Sav	26-1	pp																																																																																			
Riparian	28-1	df																																																																																			
Riparian	29-1	df	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	>	>
Riparian	29-2	pp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	>
Riparian	31-1	df																																																																																				
Riparian	31-2	pp																																																																																			
Forest	32-1	pp																																																																																				
Forest	32-2	df	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>	>	>	>	>	>	>	>	>	>	>	-	-	-	-	-	-	-	-	-	-	-	-	-
Forest	33-1	df																																																																																				

> = slow-growth periods, at least ½ previous increment

– = "normal" growth period.

#'s on top line = years.


27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 1900 99 98 97 96 95 94 93 92 91 90 89 88 87 86 85 84 83 82 81 80 79 78 77 76 75 74 73 72 71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56 55 54


53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 1800 99 98 97 96 95 94 93 92 91 90 89 88 87 86 85 84 83 82 81 80